INTERIM OBJECTIVES FOR RESTORING CHINOOK SALMON AND STEELHEAD IN THE STANISLAUS RIVER

OR

INTERIM OBJECTIVES FOR RESTORING CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) AND *ONCORHYNCHUS MYKISS* IN THE STANISLAUS RIVER

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LIST OF ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
7DADM	7-day average of daily maximum temperature
A	Adequate
AFRP	Anadromous Fish Restoration Program
ARIS	Didson imaging sonar system
ARM	Adaptive Resource Management
B	Borderline
Basin Plan	Sacramento and San Joaquin River Basins Water Quality Control Plan
BOD	biological oxygen demand
C	Catastrophic
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
CRR	cohort replacement rate
CRST	Caswell rotary screw trap
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
Delta	Sacramento-San Joaquin Delta
DO	dissolved oxygen
DPS	distinct population segment
DWR	California Department of Water Resources
DWSC	Stockton Deep Water Ship Channel
ELS	early-life stages
ERP	Ecosystem Restoration Program
ESA	Endangered Species Act
ESHE	Emigrating Salmonid Habitat Estimation
Estuary	San Francisco Bay/Sacramento-San Joaquin Delta Estuary
ESU	evolutionarily significant unit

FL	fork length
FR	Federal Register
ft	foot; feet
ft/s	feet per second
HSC	habitat suitability criteria
HSI	habitat suitability index
in	inch
IQR	interquartile range
IULT	Incipient Upper Lethal Temperatures
LC50	median lethal concentration
LT	Long-term
m	meter
m/s	meter per second
M&E	monitoring and evaluation
m^2	square meter
mg/L	milligram per liter
mm	millimeter
NMFS	National Marine Fisheries Service
NT	Near-term
OPP	Office of Pesticide Programs
pHOS	proportion of hatchery-origin spawners
PIT	passive integrated transponder
RBDD	Red Bluff Diversion Dam
RM	river mile
RST	rotary screw trap
S.M.A.R.T.	Specific, Measureable, Achievable, Relevant to overarching goals, and Time-bound
SEP	Scientific Evaluation Process
steelhead	Central Valley Steelhead
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
USDOI	U.S. Department of the Interior
USEPA	U.S. Environmental Protection Agency

USFWS	U.S. Fish and Wildlife Service
VSP	viable salmon population
WDOE	Washington State Department of Ecology
WQC Plan	Bay-Delta Water Quality Control Plan
WY	water year
YOY	young of the year

1 INTRODUCTION

Over the past few decades, efforts have been made to reverse and restore the declining health of riverine and estuarine habitats in the Central Valley, and in particular, their anadromous fish fauna. However, these habitats and key populations continue to be at risk of further degradation and decline. This lack of restoration success can, in part, be attributed to disagreements and conflicts among resource agencies, conservation groups, and water districts on appropriate strategies for conservation and restoration. More fundamentally, there is often disagreement on appropriate targets of conservation success and failure to develop restoration management strategies that prioritize conservation actions based on their ability to attain these overarching goals and objectives. Without such a framework, science-based adaptive management cannot be applied to solve complex ecosystem and water management issues.

The lack of restoration success is recognized in multiple regulatory processes associated with the lower reaches of the San Joaquin River and its major tributaries. Because these regulatory processes may affect change in both the continued risk to the fisheries and the operations of various water and resource management agencies, a large group of stakeholders interested in resolving long-standing ecosystem and water management issues convened to work on a process to negotiate a settlement for these various regulatory processes. This process, called the San Joaquin Tributary Settlement Process, originally discussed a set of goals for the overall system, but the stakeholders soon realized that science-based methods should be used to establish desired outcomes (including goals, biological objectives, and environmental objectives) for the river, and to evaluate conservation proposals in the context of those desired outcomes. Further, due to the size and complexities of the overall San Joaquin River basin, stakeholders in the San Joaquin Tributary Settlement Process decided to focus first on one major San Joaquin River tributary, the Stanislaus River.

Scientists with appropriate expertise were identified by the various parties to participate in an effort to identify a new pathway for improving the status of Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley rainbow trout and steelhead (*O. mykiss*) populations in the San Joaquin River basin. The collaboration involved experts from California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation, National Marine Fisheries Service (NMFS), American

Rivers, The Bay Institute, Trout Unlimited, and The Nature Conservancy. Although the process was open to all stakeholders, technical representatives from local water agency stakeholders participated only in the first few meetings of the group. This collaborative group pursued a Scientific Evaluation Process (SEP) and identified itself as the SEP group.

Although most of the participants recognized that state and federal laws and policies require protection of the environment beyond the needs of any single species or habitat, technical participants decided to focus their efforts on defining desired outcomes for three fish populations: *O. mykiss* (both resident and migratory forms) and the spring- and fall-runs of Chinook salmon. This decision was accepted with the belief that restoring resilient populations of these fish throughout the San Joaquin River basin would amount to major progress toward improving existing ecological conditions.

The primary task of this initial SEP collaboration was to develop objectives for the Stanislaus River that also support the broad framework for ongoing processes concerned with protecting and restoring fisheries and other environmental benefits in the San Joaquin River basin. The framework incorporates federal and state policies, programs, and plans, including the Anadromous Fish Restoration Program (USFWS 2001), the Bay-Delta Water Quality Control Plan (WQC Plan), Endangered Species Act (ESA) recovery plans, and relevant CDFW code sections. The programs and plans that the SEP group considered as part of this framework are discussed in detail in Section 2.3.1.

The SEP was intended to help provide a common scientific foundation of fact for both parties engaged in developing a comprehensive approach to solving San Joaquin River basin resource management issues, and parties engaged in relevant regulatory processes, including specifically: 1) the State Water Resources Control Board (SWRCB)'s update of the WQC Plan, as called for under both the state Porter Cologne Water Quality Control Act and the federal Clean Water Acts; and 2) Federal Energy Regulatory Commission relicensing proceedings.

The purpose of the SEP is three-fold, as follows:

- Develop a clear, scientifically justified vision for the desired status of salmonids in the Stanislaus River and larger San Joaquin River basin,

- Provide well-documented and transparent technical guidance on the conditions necessary to attain that vision,
- Evaluate the effectiveness of proposed strategies developed to achieve the conditions necessary to realize the vision for Chinook salmon and both resident (rainbow trout) and migratory (steelhead) forms of *O. mykiss* in the Stanislaus River and the San Joaquin River basin.

This report addresses the first goal, and was developed in a manner to support the other two goals, as they relate to the Stanislaus River. Future documents will produce technical descriptions and rankings of stressors related to each salmonid life stage on the Stanislaus River, and the vision and technical guidance for other major San Joaquin River tributaries (the Tuolumne and Merced Rivers) and for the mainstem San Joaquin River downstream of its confluence with the Merced to the Delta. The SEP group envisioned that the strategies proposed to achieve the conditions necessary to meet the needs of Chinook salmon and steelhead in the Stanislaus River and throughout the San Joaquin River basin would be developed through discussions and multi-party negotiations among resource agencies, conservation groups, and water districts. The proposed strategies (suites of conservation measures) would then be reviewed using a systematic process developed by state and federal agencies (e.g., the methodology described for the Delta Regional Ecosystem Restoration Implementation Program). The ultimate purpose of these efforts and strategies is to protect and further expand native living resources within the San Joaquin River basin.

2 SCOPE, CONTEXT, AND CONSIDERATIONS

2.1 Scope and Context

San Joaquin River basin salmonid populations were once some of the largest in California's Central Valley (CDFG 1990). Historically, the San Joaquin River and its tributaries supported both spring- and fall-runs of Chinook salmon and steelhead (Yoshiyama et al. 2001; Moyle 2002). As recently as the 1940s, spring-run Chinook salmon were the dominant salmon run in the San Joaquin River basin (Fry 1961).

From the 1940s to the 1980s, extensive water storage development occurred throughout the San Joaquin River watershed, resulting in a large proportion of flow being diverted from river channels. In addition, spawning and rearing habitat degraded, and access to historical spawning and rearing reaches was blocked by dams. This habitat degradation and loss caused by construction and operation of dams, along with habitat degradation caused by gravel mining, channelization, and other human actions has significantly reduced the viability of spring- and fall-run Chinook salmon and steelhead populations. For decades, spring-run Chinook salmon were considered to be extirpated from the San Joaquin River basin (Fisher 1994), although more recently the presence of "spring-running" Chinook salmon in the Stanislaus and Tuolumne rivers has been observed (Franks 2012).

2.2 Considerations for Biological and Environmental Objectives

The SEP group developed biological and environmental objectives for the Stanislaus River with the following key considerations in mind:

- Objectives are Specific, Measureable, Achievable, Relevant to overarching goals, and Time-bound (S.M.A.R.T.), and in this context, consistent with other efforts in the Central Valley.
- Biological and environmental objectives for the Stanislaus River are specific to conditions that can be controlled or greatly influenced by actions in that watershed. In cases where setting Stanislaus River-specific objectives required making assumptions regarding outcomes in other parts of the salmonid life cycle, those assumptions are stated. For example, the productivity (juvenile survival) objectives for the Stanislaus River assume and reflect anticipated improvements in survival through the Delta because it is not possible to restore adequate salmonid productivity

unless conditions improve throughout the freshwater environments used by these fish. As described below, objectives for which the Stanislaus is an essential, but not the sole, contributor (e.g., lower San Joaquin River and south Delta habitat conditions) remain to be developed.

- Biological and environmental objectives do not pre-suppose or confine the mechanisms or actions that may be deployed to attain them.
- Biological and environmental objectives are intended to serve Central Valley goals and objectives. For example, Central Valley goals and objectives that set expectations for abundance of salmonids produced by or returning to the Stanislaus River have already been identified (e.g., the Anadromous Fish Restoration Plan [AFRP] identifies a target of natural ocean production of 22,000 fall-run Chinook salmon as a 5-year running average; USFWS 2001) or were derived with reference to policy guidance and outcomes on similar systems in the Central Valley. These expectations were used to inform development of biological and environmental objectives for the Stanislaus River. However, no abundance objectives, per se, were identified for the Stanislaus River because the SEP group recognized that abundance is related to conditions throughout the salmonid life-cycle and cannot be tied solely to conditions on the Stanislaus River.
- In addition to abundance, other population parameters, including diversity, productivity, and spatial structure, are reflected in the objectives. Levels of these four parameters taken together determine if salmonid populations are viable, healthy, and in good condition and to what level of risk they are exposed (McElhany et al. 2000). These parameters influence each other directly and indirectly; for any population, failure to achieve threshold levels for any one of these parameters represents a threat.
- While the specific biological and environmental objectives reported here were developed for the Stanislaus River, they are intended to be applied in concert with analogous targets specific to all rivers in the San Joaquin River basin. Thus, creating ecological conditions in the Stanislaus River necessary to support biological objectives for the target salmonid populations is only one component of a broader strategy for supporting vibrant and diverse populations of Chinook salmon and *O. mykiss* throughout the San Joaquin River basin.
- In addition to tributary-specific objectives, San Joaquin River basin-wide objectives will need to be established in some cases. For example, the production of juvenile

salmonids from all San Joaquin River tributaries will affect the quantity and quality of rearing and migration habitats needed in the lower San Joaquin River to support the combined outmigration. Additional objectives, to which the Stanislaus will need to contribute but which depend on the relative contributions of other San Joaquin tributaries, will be developed after the SEP group develops biological goals and objectives for the Tuolumne and Merced Rivers.

- The objectives discussed in this report focus on salmonid species; however, their cumulative effect is intended to benefit numerous native species and habitat types throughout the Stanislaus River watershed, the San Joaquin River corridor, and into the Sacramento-San Joaquin Delta (Delta). Because salmonids are relatively resilient and hardy species, attainment of objectives designed to restore these populations may not represent the level of restoration of the Stanislaus River, lower San Joaquin River, or Delta required by other species or downstream ecosystems.
- To evaluate the attainment of some of the S.M.A.R.T. objectives identified here, additional monitoring may be necessary. Nonetheless, all objectives identified here are believed to be measureable using existing technology.
- Successfully restoring the sustainability and resiliency of anadromous fish populations in the Basin may require restoring access to habitats in watersheds above dams. All major rivers in the San Joaquin River basin are candidates for facilities that allow fish to successfully pass dams and access habitat in upper watersheds (NMFS 2014). The SEP made no assumptions that specific measures would occur in the future. Rather, the conservation measures developed through future discussions and negotiations are expected to respond to and serve the biological and environmental objectives identified in this report and will be evaluated as to how well they support attainment of the objectives.

2.3 Scope

The SEP group developed biological and environmental objectives for the Stanislaus River in the context of the following policy, geographical, biological, adaptive management, and peer review considerations.

2.3.1 Policy

Historically, anadromous populations of Pacific salmon were an essential food source and cultural icon for the native peoples and early European residents of North America's Pacific coast, including those people who lived along the San Joaquin River and its tributaries. Modern society places a high intrinsic value on its natural resources, and this is especially true of the iconic Pacific salmon (Layton et al. 1999). In addition, many stocks of salmon are harvested and this contributes greatly to local economies through tribal, commercial, and recreational fisheries. To protect these valuable natural resources, the federal and state governments have adopted numerous laws, programs, and plans that call for restoring healthy anadromous salmonid populations in the Central Valley and the San Joaquin River. As it developed biological and environmental objectives for restoring salmonids of the Stanislaus River, the SEP group considered and attempted to harmonize the requirements of the following laws, plans, and programs:

- **The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988.** The California Advisory Committee on Salmon and Steelhead Trout was created in 1983 to develop a strategy for the conservation and restoration of salmon and steelhead resources in California. The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 was signed by the Governor of California to implement the advisory committee's recommendations, which included doubling the natural production of salmon and steelhead as of 1988.
- **Central Valley Project Improvement Act.** On January 9, 2001, the USFWS released the Final Restoration Plan for the AFRP to comply with Section 3406(b)(1) of Title 34 of Public Law 102-575, the Central Valley Project Improvement Act (CVPIA; USFWS 2001). This section of the CVPIA requires that the Secretary of the U.S. Department of the Interior (USDOI) develop and implement a program that makes all reasonable efforts to ensure that, by the year 2002, natural production (i.e., all production excluding fish produced from hatcheries) of anadromous fish in Central Valley rivers and streams will be sustainable on a long-term basis at levels not less than twice the average levels attained during the 1967 through 1991 period. This narrative requirement is referred to herein as the "doubling goal." Production refers to the abundance of fish available to the ocean fishery and should not be confused with escapement, which refers to the number of adult fish that return to freshwater habitats to spawn. The AFRP calculates a natural production target of 990,000

Chinook salmon (including 750,000 fall-run and 69,000 spring-run fish) for the Central Valley. Of this total, the AFRP established production targets of 22,000, 38,000, and 18,000 adult fall-run Chinook salmon being produced each year in the Stanislaus, Tuolumne, and Merced rivers, respectively (USFWS 2001). Additionally, the AFRP established a target of 13,000 naturally-produced steelhead at the Red Bluff Diversion Dam (RBDD). This target represents roughly a doubling of production from the 1967 to 1991 baseline period and is a target for the upper Sacramento River watershed only. No steelhead targets have been established for the remainder of the Central Valley watershed, which would be much larger than the current (partial) target.

- **California Fish and Game Code Sections 6900-6924.** The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act declares that it is the policy of the State to significantly increase the natural production of salmon and steelhead by the year 2000, and directs the CDFW to develop a plan and program that strives to double the current natural production of salmon and steelhead resources. This is the same narrative (i.e., a doubling goal) as in the CVPIA.
- **California Fish and Game Code 2760-2765.** As described in California Department of Fish and Game (CDFG) Code 2760-2765, the purpose of the Keene-Nielsen Fisheries Restoration Act of 1985 is to: 1) prevent further declines in fish and wildlife; 2) restore fish and wildlife to historical levels where possible; and 3) enhance fish resources through the protection of, and an increase in, the naturally spawning salmon and steelhead resources of the state.
- **State Water Resources Control Board's 2006 Water Quality Control Plan (WQC Plan).** The WQC Plan contains the current requirements under federal Clean Water Act section 303(c)(33 U.S.C., § 1313(c)) and Section 13240 of the state Porter-Cologne Water Quality Control Act to protect the beneficial uses of the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Estuary). Specifically, it identifies beneficial uses of water in the Estuary, including its watershed, water quality objectives to protect those beneficial uses, and a program of implementation for achieving the water quality objectives. In the 2006 plan, the narrative objective for salmon protection states that "Water quality conditions shall be maintained, together with other measures in the watershed, sufficient to achieve a doubling of natural production of Chinook salmon from the average production of 1967 to 1991,

consistent with the provisions of state and federal law (SWRCB 2006)." In Phase I of its update of the 2006 plan, the SWRCB is considering the adoption of new flow objectives on the Lower San Joaquin River and its three eastside tributaries for the protection of fish and wildlife beneficial uses. A revised environmental analysis is scheduled for release in late 2015.

- **Endangered Species Act Determinations and Plans.** In 1999, the NMFS listed the Central Valley spring-run Chinook salmon evolutionarily significant unit (ESU) as threatened under the ESA of 1973 (64 Federal Register [FR] 50394). In 1998, NMFS listed the distinct population segment (DPS) of steelhead in the Central Valley as threatened under ESA (63 FR 13347). Recent status reviews conducted by NMFS resulted in no changes being made to the status of these populations under ESA (NMFS 2011a, 2011b). In the context of the ESA, recovery is defined as an improvement in the status of a listed species to the point at which listing is no longer appropriate under the ESA. In June 2014, NMFS released a final plan for the recovery (i.e., delisting) of the Central Valley spring-run Chinook salmon ESU and the steelhead DPS. In 1999, NMFS considered new information about the Central Valley fall-run and late fall-run Chinook salmon ESU. NMFS determined that listing was not warranted at that time but considered these to be candidate species for listing in the future. The ESU was transferred from the candidate list to the species of concern list in 2004 (NMFS 2009a).
- **Ecosystem Restoration Program.** The Ecosystem Restoration Program (ERP) (http://www.dfg.ca.gov/erp/) is a multi-agency effort aimed at improving and increasing aquatic and terrestrial habitats and ecological function in the Delta and its tributaries. The principal participants that oversee the ERP are CDFW, USFWS, and NMFS, collectively known as the ERP Implementing Agencies. The program originated as part of the CALFED Bay-Delta Program, and continues, pursuant to the Delta Reform Act of 2009, to fund projects with state funding sources and partnerships under the leadership of CDFW. The ERP is guided by the updated 2014 Conservation Strategy, which includes objectives for restoration of salmonid habitats and populations in the San Joaquin River basin.
- **California Endangered Species Act.** The CDFW holds California's fish and wildlife resources in trust for the people of the State. As such, CDFW is responsible for statewide protection of fish and wildlife species and their habitat through the

implementation and enforcement of California's fish and wildlife laws, including the California Endangered Species Act (CESA). The CDFG Commission listed Central Valley spring-run Chinook salmon as a threatened species under the CESA in 1999 based on the recommendation of CDFW (CDFG 1998).

- **California Fish and Game Code § 5937.** This section of the CDFG Code was placed into the code by the California Legislature to balance the needs of California's native fish and the construction and operations of dams in 1915 (Börk et al. 2012). Although this section of the Code was not enforced much through the 1970s (Börk et al. 2012), this changed in the 1970s, first with a decision by the State Water Resources Control Board in 1975 (SWRCB 1975) and then with the decision by the Court of Appeals on suit brought by California Trout concerning Mono Lake tributaries (California Trout, Inc. v. State Water Resources Control Board ("CalTrout I") 1989). Though several recent papers have discussed CDFG Code 5937, one of the most pertinent is Grantham and Moyle (2014) where they developed and applied a screening framework focusing on indicators of hydrological alteration and fish population impairment to identify dams for which environmental flows may be warranted.
- **San Joaquin River Restoration Program.** After the completion of Friant Dam by the federal government in the 1940s, nearly 95% of the river's flow below the dam was diverted. As a result, 60 miles of the river ran dry, the second largest salmon population in the state was lost, and local fish and wildlife populations declined. Decreased water flows and water quality degradation also impacted downstream farms and communities. Since 2009, the U.S. Bureau of Reclamation, USFWS, NMFS, CDFW, and the California Department of Water Resources have been working together to implement this program (resulting from a 2006 legal settlement between environmental groups, the Friant Water Users Authority and the federal government, and subsequent federal legislation) to restore both spring-and fall-run Chinook salmon to the mainstem San Joaquin River downstream of Friant Dam. The long-term goal is to restore runs of up to 30,000 spring-run and 10,000 fall-run annually.

The biological and environmental objectives developed by the SEP group for the Stanislaus River were designed to contribute to the goals of ESA, CVPIA, CDFG code, and the WQC Plan. The intent of the SEP was to develop a framework of clearly expressed technical guidance that would result in restoring populations of all anadromous salmonids consistent with all relevant policies. For example, Central Valley spring-run Chinook salmon and steelhead are listed under ESA and fall-run Chinook salmon are not listed; the doubling of Chinook salmon runs is required under the WQC Plan, the CDFG Code and the CVPIA, and the doubling of steelhead under the CDFG Code and CVPIA.

2.3.2 Geographical

The SEP group focused on the Stanislaus River as a first step toward developing a clear and transparent framework for identifying the restoration needs of waterways in the San Joaquin River basin. Plan Goals and biological and environmental objectives are specific to outcomes that can be attained by actions on the Stanislaus River; they represent the necessary contributions from the Stanislaus River to restoration of salmonids (and, hopefully, other species) throughout the San Joaquin River basin. Additionally, the SEP group recognized that the Stanislaus River must contribute to conditions in the lower San Joaquin River and southern Delta, but, in many cases, it is not possible to completely define that contribution without performing a similar evaluation of goals and objectives for the other rivers in the San Joaquin River basin. Thus, the biological and environmental objectives for the lower San Joaquin River (to which the Stanislaus River and other tributaries will contribute) are described incompletely at this time. The SEP group's intent is that the template developed for the Stanislaus River will be used to develop similar sets of biological and environmental objectives for the Tuolumne, Merced, and lower mainstem San Joaquin rivers in the future.

Currently, the SEP group estimates that the survival of fall-run Chinook salmon through the Stanislaus River below Goodwin Dam to the San Joaquin's entry into the Delta is extremely low (less than 2%; Section 6.2.1). However, despite its poor condition, the Stanislaus River is widely believed to provide the best salmonid habitat conditions available to Chinook salmon and steelhead throughout the San Joaquin River basin.

The SEP group chose the Stanislaus River as its focus river because of its current habitat conditions and potential for restoration, and because of the relative amount of information available on this river compared to others in the San Joaquin River basin. It was also addressed first in response to the interests of the SWRCB and other WQC Plan process stakeholders who are considering establishing new flow objectives on the lower San Joaquin River and its three eastside tributaries, the Merced, Tuolumne, and Stanislaus rivers.

The spatial scope of this initial effort to develop biological and environmental objectives for the Stanislaus River includes the Stanislaus River from Goodwin Dam to its confluence with the San Joaquin River (Figure 1). While the biological and environmental objectives are specific to reaches within the Stanislaus River, the SEP group recognizes that establishing biological objectives for Chinook salmon and steelhead in the Stanislaus River and identifying the ecological conditions required to support them does not end at the Stanislaus River. Suitable habitat conditions in the lower San Joaquin River are necessary for the successful restoration of Chinook salmon and steelhead populations in the Stanislaus River. Therefore, the SEP group quantified some environmental objectives for the lower San Joaquin River in situations where those conditions are independent of the biological objectives for the Merced and Tuolumne rivers. For example, the environmental objectives of temperature and dissolved oxygen (DO) are not affected by the total number of fish using the lower San Joaquin River. By contrast environmental objectives for habitat quantity in the lower San Joaquin River will be determined, in part, by salmonid productivity elsewhere in the San Joaquin River basin. In addition, the SEP group quantified biological objectives in the lower San Joaquin River for fish originating in the Stanislaus River and migrating through the lower river.

Biological objectives for the Estuary and Pacific Ocean were not addressed because these ecosystems respond to ecological drivers and human actions that are beyond the scope identified for the SEP group's consideration. However, the SEP group identified assumptions about current and future conditions in the Estuary and marine environments when such assumptions were necessary to establish targets within the San Joaquin River basin. For example, in developing biological objectives for the Stanislaus River, the SEP group assumed that mortality associated with ocean fisheries would remain unchanged. Changes in marine harvest rates and regulations are determined in other policy forums and, in any case, would have minimal effect on the current Chinook salmon total survival rates. For example, even completely eliminating the ocean fishery would perhaps double total survival, whereas freshwater survival in the San Joaquin River basin currently is less than 1% of a healthy, more typical salmon population (Winship et al. 2013). The assumptions that the SEP group made about marine and estuarine survival rates are transparent and may be adjusted, if desired, to determine their implications for salmonid restoration in the San Joaquin River basin. In addition, biological objectives for survival and routing through the Delta were not addressed because they are being established in other forums.

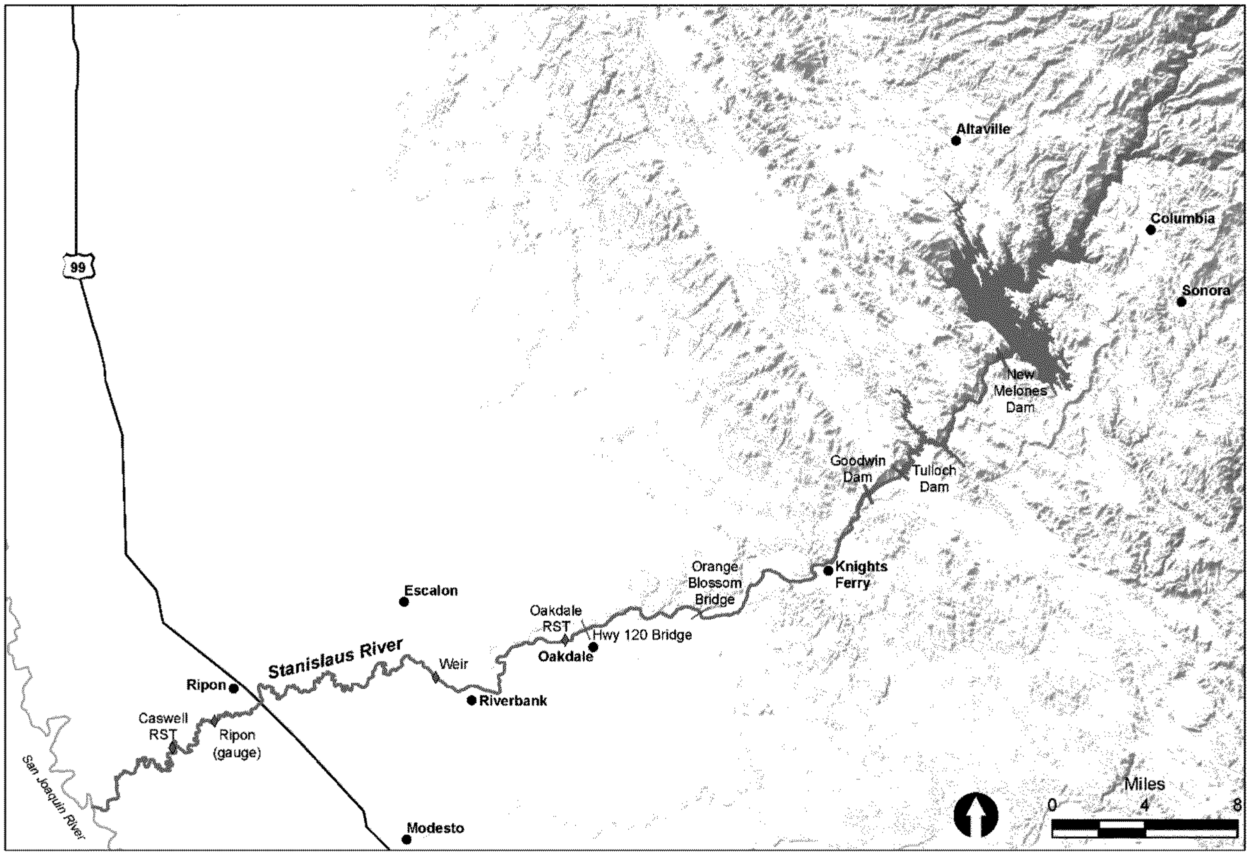


Figure 1

Key Dams and Features of the Lower Stanislaus River

Source: NMFS 2014

Although this initial effort was focused on riverine habitat below Goodwin Dam, the SEP group recognizes that successfully restoring the sustainability and resiliency of anadromous fish populations in the San Joaquin River basin may require restoring access to habitats in watersheds above dams. Indeed, all major rivers in the San Joaquin River basin are candidates for facilities that allow fish to successfully pass dams and access habitat in upper watersheds (NMFS 2014). Potentially available anadromous salmonid habitat located above New Melones Dam on the Stanislaus River is shown in Figure 2.

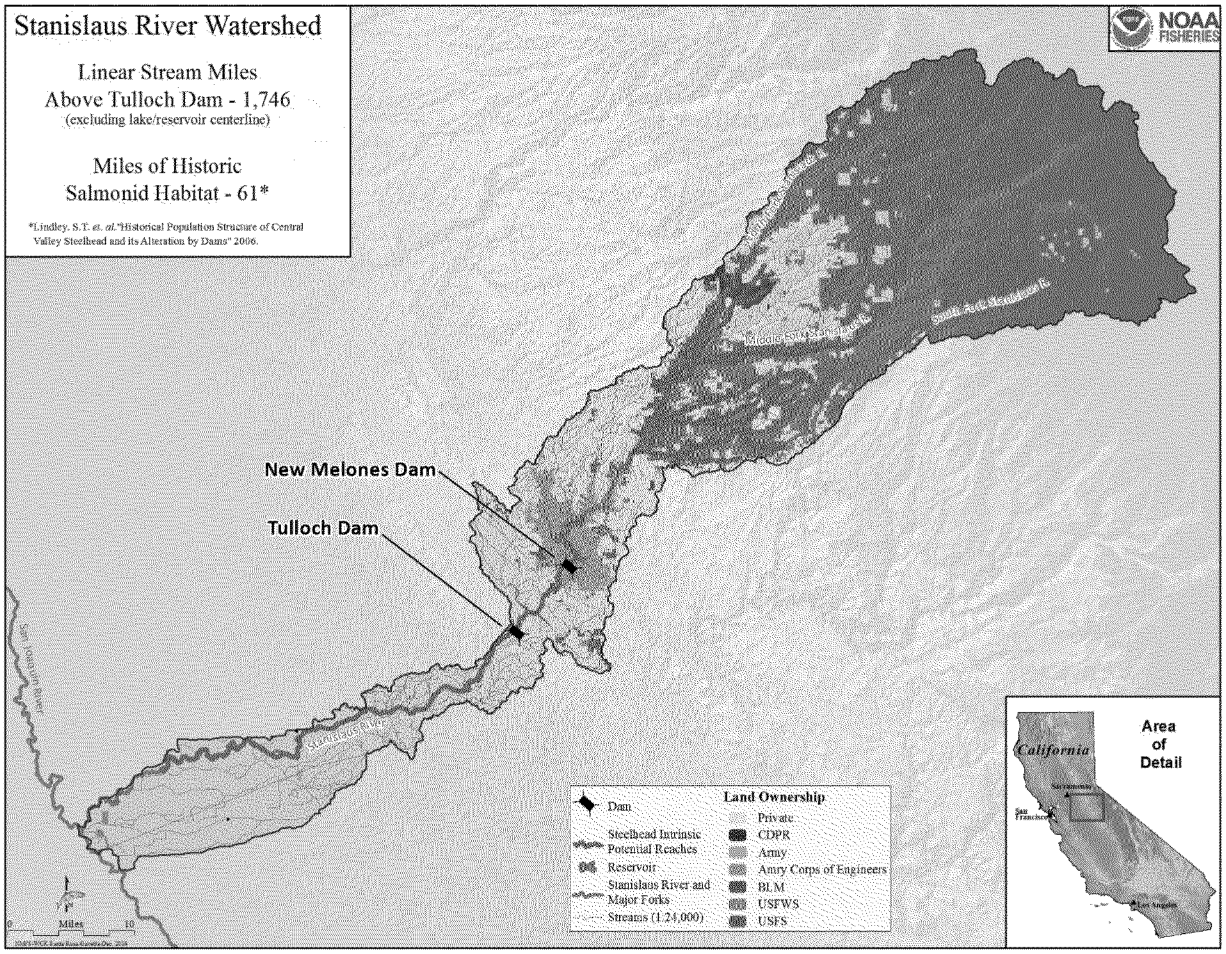


Figure 2
The Stanislaus River Watershed

2.3.3 Biological

The overarching intent of the SEP is to restore native species and ecosystem processes to desirable levels on the Stanislaus River and throughout the San Joaquin River basin. However, the scope of the SEP group's effort was constrained by the availability of adequate policy guidance and data necessary to set biological and environmental objectives. Salmonids are the focus of many policies regarding environmental and water management in the Central Valley and they are among the best monitored and studied organisms in this area. Thus, the SEP group constrained its scope to focus on biological and environmental objectives related to salmonid restoration. Achievement of all biological objectives for a given population is intended to result in a population that is viable, healthy, and sustainable.

The objectives developed by the SEP group focused on the following species/runs:

- Fall-run Chinook salmon. This population exists on the Stanislaus River and elsewhere in the San Joaquin River basin at levels of abundance that are less than required by the Central Valley Project Improvement Act (CVPIA) and AFRP, the state and federal Clean Water Acts, and related state laws and policies. The current adult returns are also known to have a high level of stray hatchery fish from other river basins (Palmer Zwahlen and Kormos 2013).
- Spring-run Chinook salmon. A limited number of fish exhibiting a spring-running phenotype have been observed on the Stanislaus River over several years (Franks 2012). However, the establishment of a viable, self-sustaining spring-run population has not been confirmed and is not formally acknowledged by the trustee agencies to exist in the Stanislaus River or other waterways in the San Joaquin River watershed at this time. A reintroduction program to the San Joaquin mainstem upstream of its confluence with the Merced River is being initiated as part of the San Joaquin River Restoration Program, and the first juvenile fish from that effort were released to outmigrate in April 2014. Additionally, NMFS has identified the need to restore spring-run Chinook salmon populations in tributaries of the San Joaquin River as part of the Central Valley Chinook Salmon and Steelhead Recovery Plan (NMFS 2014). Therefore, biological objectives for this run of Chinook salmon were developed to support the reestablishment of the run in the Stanislaus River.
- Steelhead. This anadromous life-history form of *O. mykiss* exists at a low level in the Stanislaus River. The complex life-history of steelhead and the limited amount of monitoring data on the species from the San Joaquin River basin's rivers create a unique challenge for describing biological objectives. The objectives presented here acknowledge the potential and desireability for *O. mykiss* to mature as either a resident or anadromous form, and focus on the need for increased life-history diversity of the species in the watershed.

The SEP group acknowledges that attaining the biological and environmental objectives for these salmonids, and the resultant environmental conditions in the tributaries, would not restore all of the important ecological and physical functions of the San Joaquin River basin's rivers. In addition, establishing conditions necessary to attain biological objectives for salmonids in the San Joaquin River basin's tributaries may not result in conditions necessary for achieving sustainable benefits in the Delta and Estuary.

2.3.4 Adaptive Management and Peer Review

The SEP group recognizes that adaptive management and peer review are critical components of any resource management process because decisions are almost always made with some degree of uncertainty. Good decisions of this nature are defined by the process in which they were generated, and by the degree to which the decision framework is designed to incorporate new information as it becomes available to reduce uncertainty and improve decision outcomes (Williams et al. 2009).

The SEP group considers the biological objectives it developed to be the minimum conditions necessary to achieve the global goal. Therefore, adaptive management should be used to ensure that conservation measures perform as intended to achieve the stated environmental objectives and ultimately the biological objectives. These objectives were designed to be S.M.A.R.T. Information developed through monitoring will need to be synthesized and used to adjust the conservation measures. If monitoring indicates that conservation measures are not performing as intended, changes should be implemented to ensure that biological objectives are reached. Conversely, if biological objectives are attained prior to implementing the full suite of conservation measures, the full implementation plan can be modified. Implementation of the conservation measures will require various levels of monitoring, including system-wide monitoring to document compliance and evaluation of overall effectiveness.

The SEP group also understands the need for peer review. The interim biological and environmental objectives will be reviewed and critiqued. While no formal process for peer review has been incorporated into the SEP, it is expected that peer review will occur as the biological and environmental objectives are reviewed, and conservation measures to address the objectives are discussed and developed.

The SEP group anticipates that the need for, and the potential structure of, a more detailed adaptive management framework and peer review process will be discussed in conjunction with the development of conservation measures. Aspects of adaptive management and peer review that the SEP group is considering at this time are discussed in Section 9.

2.4 Key Terms and Definitions

The key terms and phrases used throughout this report are defined and described below.

Problem Statement. For each target species and for the ecosystem as a whole, problem statements provide a concise declaration of the ecological issues that require attention. A comprehensive conservation plan would need to address each of these issues for the problem to be solved. Problem statements are general and factual descriptions of the problem(s) and do not assume particular causes of, or solutions to, those problems. For target species, a problem statement would address, at a minimum, each attribute of viability for which the species is deficient. For example:

> Central-valley spring-run Chinook salmon populations are imperiled because abundance is well-below desired levels, survival rates are inadequate to sustain population growth, populations are severely constrained geographically, and the populations express only a narrow range of the life-history variants that are typical of this species.

Central Valley Goals. Central Valley Goals disaggregate the challenges facing species or the ecosystem into components (e.g., the viable salmonid population [VSP] parameters of abundance, diversity, productivity and spatial structure) and state desired outcomes that will solve the issue(s) identified in the problem statement. Again, these are simple, factual statements and do not pre-suppose a mechanism for solving the problem. The goals are "Central Valley" goals because they describe outcomes that may be partially or completely beyond the scope of any particular plan and do not extend to a species' range-wide conservation challenges. Identification of these global goals is important to create a context for the overall conservation strategy. Global goals and associated targets are often delineated by agency plans (e.g., as identified in conservation or recovery or water quality plans), regulations (e.g., CDFG code) or in legislation (e.g., CVPIA). For example:

> One Central Valley goal for spring-run Chinook salmon is to increase the spatial distribution of independent, viable spawning populations, including establishment of populations in the Southern Sierra Diversity group (NMFS 2014).

Central Valley Objectives. Central Valley objectives provide specificity to a desired biological outcome (i.e., a related Central Valley goal). Objectives are S.M.A.R.T. statements that indicate what level of restoration constitutes attainment of the goal. Central Valley objectives provide a clear standard for measuring progress toward a goal. As with Central Valley goals, Central Valley objectives may be only partially relevant to the activities of a particular plan; their function is to define a magnitude of the problem and set a context for planning so that investment in conservation activities is appropriately scaled to the conservation challenge.

Scope. To identify relevant targets for a specific plan, Central Valley-wide goals and objectives are filtered through the biological, geographic, and policy lenses that constrain that current planning effort. For example, the current effort will work watershed by watershed to develop desired conditions (i.e., biological and environmental objectives) for the San Joaquin River tributaries and lower San Joaquin River mainstem. The outcomes required for each watershed are not the same as those for the Central Valley system as a whole, but they are intended to support attainment of the Central Valley goals and objectives. For instance, there are Central Valley-wide goals and objectives for the abundance and distribution of Chinook salmon runs and steelhead, but these will not result solely from conditions set for the Stanislaus River. Rather, the SEP group identified biological objectives for life-history diversity and survival rates (productivity) on the Stanislaus River and lower San Joaquin River, because those objectives will support and serve attainment of escapement targets and other Central Valley goals and objectives.

Plan Goals. Plan goals articulate the particular local outcomes that would contribute to attainment of the Central Valley goals and objectives within the confines of the geographic and policy scope for the Phase 1 planning effort. These simple, factual statements describe the contribution to Central Valley goals and objectives that can be attained within a particular watershed or geographic unit—again, they do not pre-suppose a mechanism for solving the problem. For example, in the current effort, the SEP group determined that the tributaries could not be "held responsible" alone for salmonid ocean production targets, because achieving those targets would require additional conservation effort throughout the salmonid life cycle. However, the SEP group also determined that tributary-specific goals and objectives could be set for life-history diversity and productivity (survival rates) that would support attainment of Central Valley goals and objectives for salmonid production and that these goals and objectives could be defined and attained within the tributaries, regardless of conditions beyond the tributary. For example:

> *Achieve freshwater survival rates for fall-run Chinook salmon that are typical of other self-sustaining populations of ocean-type Chinook salmon.*

Biological Objectives. Biological objectives are the S.M.A.R.T. definitions of Plan Goals. In other words, they are the biological outcomes that define success in the area proscribed by the scope. For example:

> *Freshwater survival rates (egg-smolt) for fall-run Chinook salmon spawned on the Stanislaus River will be XX% by year XXXX of the plan.*

Environmental Objectives. Environmental objectives define the physical, chemical, and biological conditions that the SEP group believes are needed to attain the biological objectives. These values may be habitat, species, and life-stage specific and are derived from published literature (e.g., temperature and DO limits), conceptual and quantitative conceptual models (e.g., area of inundated floodplain), and professional judgment. These values are specific, measureable, and achievable. They are intended to serve attainment of related biological objectives and provide specific guidance for design and prioritization of conservation measures; as such, they must also be time-bound. Timing for attaining environmental objectives must occur prior to the related biological objective. Also, it is not intended that producing these necessary conditions will substitute for attainment of the biological objectives.

Current Conditions. For each relevant environmental variable, data on their recent magnitude, range, and patterns of variation will be compiled to the extent practicable. Data on current conditions will be used to determine the extent (i.e., spatially and temporally) that the environmental objectives are currently being achieved. These data will be vital for informing and ranking conservation priorities.

Conservation Need. Simply put, the difference between an environmental objective and the current condition for that environmental variable is the conservation need. Although target species have different thresholds and different reaction norms for different environmental variables, assessment of conservation needs will be essential to ranking and prioritizing proposed conservation measures.

Conservation Measures. Conservation measures are actions and associated design criteria that are proposed and taken to achieve Plan Goals and biological objectives by meeting environmental objectives. These actions may include flow regime modifications and non flow measures.

The Lower San Joaquin River. The area of the watershed downstream of the confluence of the San Joaquin and Merced rivers and upstream of the Delta (Figure 3). For the purposes of this document, the SEP group defines the Delta as River Mile (RM) 54 or the I-5 Bridge at Mossdale. This site was selected because the SEP group assumed that the effects of Stanislaus River conservation measures (i.e., flow) should reach this location under suitable flows during migratory periods and because it represents the upper-most location in the Delta where outmigrating juvenile salmonids fish can be sampled.

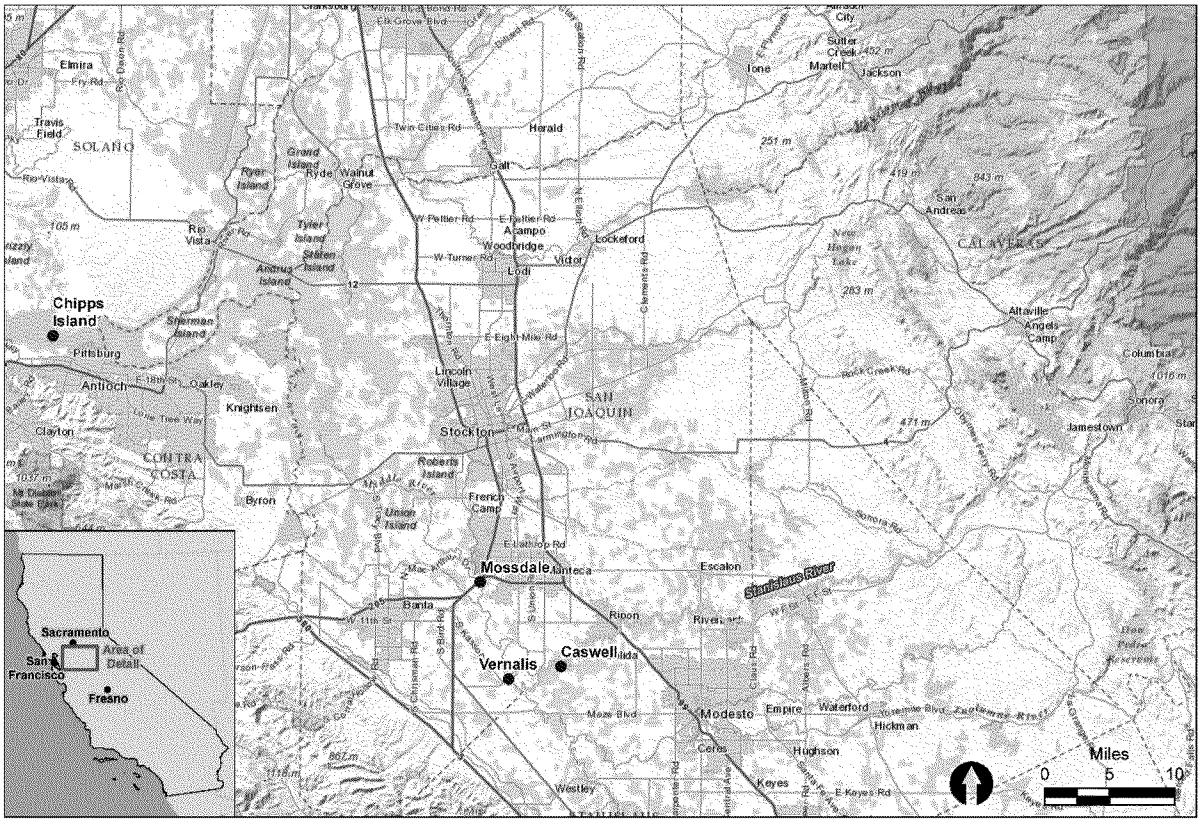


Figure 3

Map of Lower Stanislaus River and its Relationship to Sacramento-San Joaquin Delta

Source: NMFS 2014

2.5 Process Used in Developing Biological and Environmental Objectives

The SEP group utilized the following process (i.e., a logic chain) in developing the biological and environmental objectives for Chinook salmon and steelhead in the Stanislaus River using the terms identified in Section 2.4:

- What is the problem?
  - Problem statement: For example: "The species is in rapid decline."
- What outcome(s) will solve the problem?
  - Central Valley goals: High-level statements that address desired states (e.g., VSP criteria) applicable at a broader geographic or system-wide scale.
- What does solving the problem and attaining the goal look like?

- Central Valley objectives: Specific description of the targets that satisfy Central Valley goals for specific populations. Objectives are S.M.A.R.T. and define, in specific terms, what levels of a variable are needed to attain a particular goal and a date when that goal should be attained.

- How much will this effort contribute to the attainment of Central Valley objectives?
  - Consideration of the scope (e.g., geographic and policy) for the planning effort enables identification of the Central Valley goals that can be addressed within that scope. Plan Goals are a subset of the Central Valley goals, and the plan's biological objectives are tailored to support attainment of Central Valley objectives.
- What is the suite of species-specific conditions (i.e., the biological objectives) that characterize success?
  - S.M.A.R.T. objectives related to focal species or populations are specific targets that must be attained within the plan's scope in order to support Central Valley goals and objectives (e.g., what species specific conditions must be achieved or exist in the Stanislaus River in order to attain the Central Valley objectives?).
- What factors limit or prevent attainment of the environmental objectives?
  - Identification of factors that directly stress the species or limit the ability for environmental objectives to be achieved (i.e., target levels for one or multiple parameters to be attained), and their prioritization based on the scope (number of parameters and their relative importance), scale (spatial or temporal extent), and magnitude (severity of impact) of their effects currently, and as targets are approached.
- What is the suite of physical and ecosystem conditions (environmental objectives) that characterize success?
  - S.M.A.R.T. objectives related to "on the ground" conditions related to habitat quality and ecosystem function that must be attained within the plan's scope in order to achieve the biological objectives.
- What actions (conservation measures) can be taken to achieve the environmental objectives?
  - Specific actions designed to relieve stressors and achieve the environmental

objectives.

- How much will these actions (respectively or in combination) contribute to achieving the environmental objectives?
  - What are the specific projected outcomes anticipated from each conservation measure alone, and in conjunction with other conservation measures?
- How to prioritize or select between multiple conservation measures?
  - The SEP group will use a formal structure for evaluating the technical merits of proposed conservation measures that incorporates: 1) their potential to achieve desired conditions; 2) the number of desired conditions that they contribute toward; 3) the relative contribution of those conditions to the attainment of the biological objectives (i.e., the relative priority of the stressors those conditions resolve); 4) their likelihood of success; 5) their potential for unintended negative consequences; and 6) other factors.

For each species and run of Chinook salmon and steelhead discussed in this report, development of the biological objectives centered around achieving two primary goals: 1) supporting the fullest expression of life-history diversity to increase population stability, resilience, and productivity; and 2) supporting productivity (survival) rates that characterize a viable population that are necessary to attain global abundance and productivity objectives. Based on these goals, the SEP group developed two levels of the associated restoration planning process: 1) biological objectives related to life-history and productivity attributes of viability; and 2) environmental objectives needed to support the biological objectives now or in the future. Figure 4 depicts the process the SEP group used to develop the biological and environmental objectives.

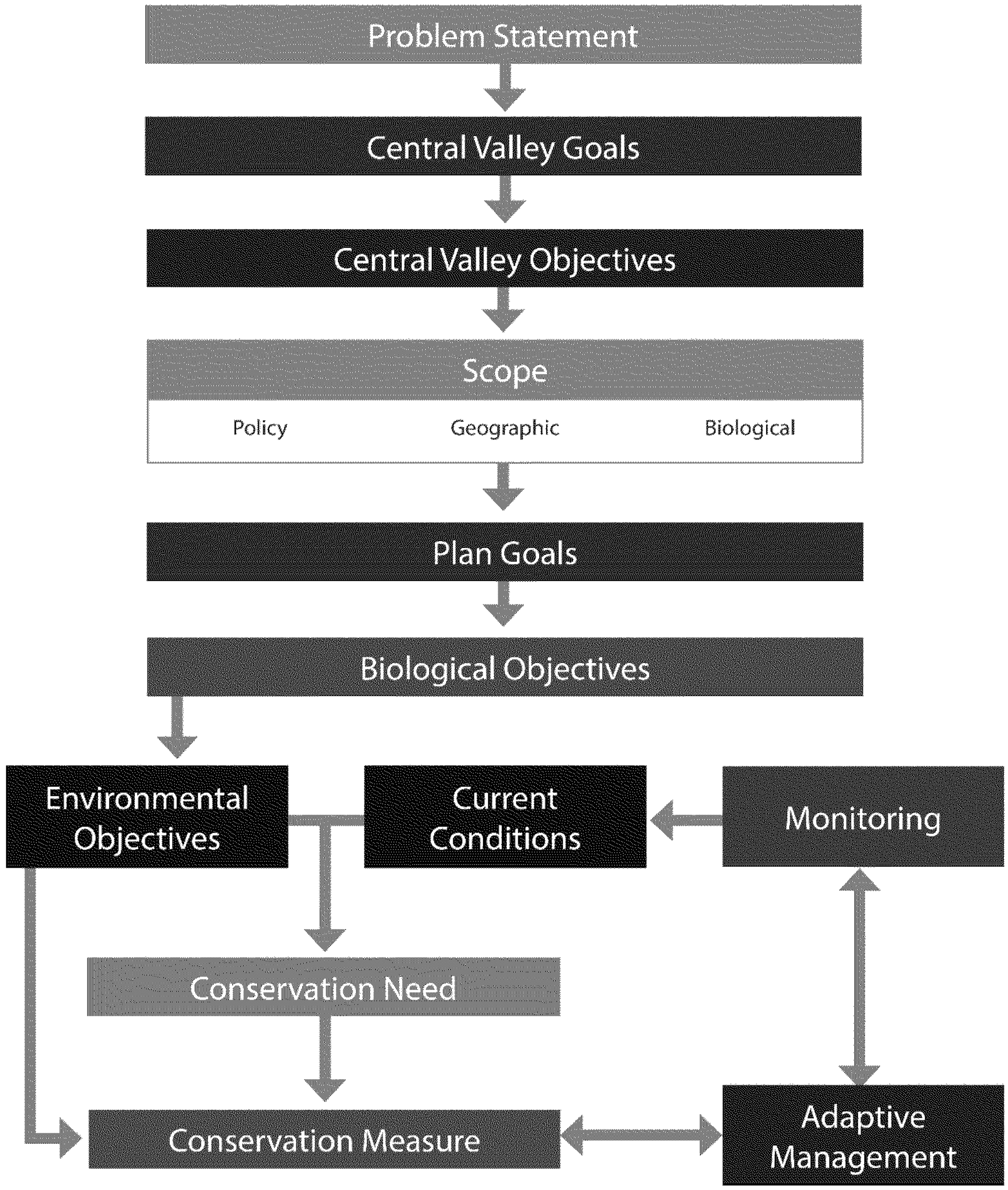


Figure 4
Scientific Evaluation Process Logic Chain

3 VIABLE SALMONID POPULATION ATTRIBUTES

Abundance, life-history and genetic diversity, productivity, and spatial structure are key attributes of viable populations (McElhany et al. 2000; Lindley et al. 2007; NMFS 2014). Together these four attributes are referred to as the VSP parameters. The VSP parameters also reflect general processes that are important to all species and are measurable (McElhany et al. 2000).

The VSP concept is a useful construct for identifying what a healthy population looks like and prioritizing the threats limiting a population's health. These threats could be from demographic variation, genetic diversity, or variation in environmental conditions. The SEP group relied heavily on the VSP concept when developing biological and environmental objectives for restoring Chinook salmon and steelhead populations in the San Joaquin River basin. The biological objectives described in this report address each of the four VSP parameters. While the degree to which each parameter was used varied among biological objectives, all four VSP parameters are considered significant components of the biological objectives. Collectively, the parameters inform the ecosystem and habitat conditions needed to reestablish and expand Chinook salmon and steelhead populations in the San Joaquin River basin.

3.1 Abundance

Abundance, or the number of organisms in a population, is a common and obvious species conservation and management metric. Populations or species with low abundance are generally less viable and at higher risk of extinction than large populations for reasons that include increased susceptibility to environmental variation, demographic stochasticity, loss of genetic diversity, and interruption of mating systems. Abundance correlates with, and contributes to, other viability parameters including spatial structure (i.e., distribution and extent), diversity, and productivity. Simply increasing the abundance of organisms (or any other single viability parameter) is not sufficient to guarantee viability into the future. In other words, population viability depends on maintaining acceptable levels of each attribute of viability.

Abundance is also a key metric for determining acceptable levels of harvest for commercially and recreationally valuable species like Chinook salmon. As a result, population abundance targets for this species must well exceed the minimum necessary to insulate the population from extinction threats. Production targets (i.e., abundance, measured as the number of fish that reach the age where they are targeted by the ocean fishery) have been set for all Central Valley rivers and are incorporated into numerous state and federal policies and regulations such as the AFRP (USFWS 2001) and the WQC Plan (SWRCB 2006).

3.2 Diversity: Genetic and Life-history

The SEP group recognizes that genetic diversity and life-history diversity are interrelated components. With respect to genetic diversity, the ability of Chinook salmon and steelhead to navigate and spawn in the rivers where they were born contributes to the highly variable life-history patterns and genetic diversity characteristics of many salmonids by facilitating local adaptation (Taylor 1991; Waples 1991). Genetic differences among the different ESUs (or runs) of Chinook salmon are maintained because many of the life-history traits, like the season of adult migration for example, are genetically inherited (Banks et al. 2000; Carlson and Seamons 2008). Thus, individuals within an ESU have locally-adapted gene complexes that improve the survival of their offspring in that habitat (Waples 1991). Introgression among the ESUs or between hatchery and natural salmon sources can function to break down these gene complexes, thereby changing life-history traits and potentially reducing the success of offspring (Ford 2002; Araki et al. 2007). Therefore, to maintain and expand the diversity and productivity of runs of Chinook salmon in the Central Valley, and allow these runs to respond to future climate variation, it is important to allow Chinook salmon the opportunity and river conditions to successfully reproduce with similarly-evolved individuals.

Life-history diversity is often cited as a crucial component of salmonid population resiliency. This is based on theoretical and empirical evidence that the maintenance of multiple and diverse salmon stocks that fluctuate independently of each other reduces extinction risk and long-term variation in regional abundances (Roff 1992; Hanski 1998; Hilborn et al. 2003; Schindler et al. 2010). This "portfolio effect" of spreading risk across stocks can also act at the within-population scale (Greene et al. 2009; Bolnick et al. 2011). For example, juvenile Chinook salmon leave their natal rivers at different sizes, ages, and times of the year, and this life-history variation is believed to contribute to population resilience (Beechie et al. 2006;

Miller et al. 2010; Satterthwaite et al. 2014). Thus, preserving and restoring life-history diversity is an integral goal of many salmonid conservation programs (Ruckelshaus et al. 2002). Finally, it is increasingly recognized that strengthening a salmon population's resilience to environmental variability (including climate change) will require expanding habitat opportunities to allow a population to express and maintain its full suite of life-history strategies (Bottom et al. 2011).

Central Valley Chinook salmon exhibit diverse outmigration timings that have evolved over geological time scales in response to the unpredictable hydro-climatic conditions characteristic of the region (Spence and Hall 2010). The expression and survival of Chinook salmon migratory phenotypes have been observed to vary under different hydro climatic regimes, emphasizing the importance of maintaining diversity in the face of increasing environmental variability (Sturrock et al. in review). However, modern-day management practices tend to constrain outmigration timing, exacerbating the risk of a temporal mismatch with favorable or unfavorable freshwater, estuarine, and ocean conditions. The portfolio effect for Central Valley Chinook salmon stocks is estimated to be currently weak and deteriorating (Carlson and Satterthwaite 2011). In addition, San Joaquin River Chinook salmon populations face serious future challenges due to the predicted 25% to 40% reduction in snowmelt by 2050 (DWR 2010).

As with Chinook salmon, life-history diversity is critical to the success of steelhead populations. Steelhead are one of the most successful salmonids on the planet, with a widespread native distribution across western North America and eastern Asia and a near planet-wide peak in distribution currently from more than 100 years of stocking for recreational fisheries. One of the reasons that this species has been so successful is because of its highly variable life-history. This variability is evident at multiple scales, because steelhead have the ability to: 1) exist as anadromous or adfluvial forms; 2) rear in high elevation headwater streams or coastal estuaries; and 3) reside in lakes.

Studies have shown that juvenile steelhead need to reach a minimum smolt size of approximately 140 millimeter (mm) (5.5 inches [in]) fork length (FL) to survive to maturity (Bond et al. 2008; Ward et al. 1989). As river systems vary widely in productivity, steelhead parr can take anywhere from 1 to 3 or more years to reach this size, so smolt ages vary depending on parr growth rates (Seelbach 1993). Age at first maturity can range from 1 to 4 years in the ocean, with jacks spending just one, and most adults 2 or 3 years in marine environments before sexually maturing. Unlike Pacific salmon, adults have the ability to spawn several times in their lifespan. This repeat spawning helps compensate for the relatively small run sizes relative to salmon, and the fact that in some watersheds in a given year the stream might have no connection to the ocean, or be scoured out by a flood, or some other natural factor could limit successful reproduction. Spawning timing can last several months (typically December to April), and emigration of smolts can also span several months (typically February to June).

Variability in smolt age, age at first maturity, spawning timing, and smolt emigration all combine to produce a species that is highly adaptable to a wide range of stream environments, and enable it to succeed in many different types of aquatic habitats, from large glacial fed rivers in Alaska to small coastal streams in southern California. Steelhead are most abundant in large rivers with high quality spawning and rearing habitat, but are also present in small coastal streams, where they can take advantage of freshwater lagoons for rearing when upstream flows are very low. At the southern edge of their range, they even persist in streams that may not be connected to the ocean in years with low rainfall.

An important property of wild steelhead populations that emerges from this variation is that there are usually not distinct cohorts of adults, such as is often seen in coho salmon, which tend to smolt and mature at fairly predictable ages. Wild adult steelhead populations are typically a mix of many cohorts, with fish that smolted at 1 to 3 years of age, matured after 1 to 3 years at sea, with some on their second or third spawning run. Total ages of the adults can range from 2 to 7 or more years. The loss of one cohort to a poor year is not as critical to the viability of the population as it would be if the entire population was based on one or two strong cohorts.

Within the Central Valley, the extensive loss of historical habitat due to dams, and the poor quality of the remaining spawning, rearing, and migratory habitats have led to a drastically reduced overall abundance of *O. mykiss*, and the near-loss of the steelhead (i.e., anadromous) form in many watersheds. The steelhead form is especially sensitive to habitat loss, as it requires not only high quality fluvial spawning and rearing areas, but also open migratory corridors with good survival rates, and reasonable ocean survival and productivity in order to persist. Currently, many rivers in the Central Valley are dominated by one form of *O. mykiss*, the freshwater fluvial, or resident, form. The steelhead form is now largely dominated by hatchery fish, all of which are released as age-1 smolts, and increasingly mature after only 1 year in the ocean. Reversing the loss of life-history diversity in *O. mykiss* and establishing conditions that favor the anadromous form to be expressed will require extensive habitat improvements, both in the rivers and the Delta.

3.3 Productivity

Productivity represents the ability for populations to grow when conditions are suitable, which is essential to conservation success. Species or populations that display persistent negative population growth, as well as populations with limited ability to respond positively to favorable environmental conditions, are less viable and are at higher risk of extinction. The productivity parameters used in developing biological objectives for the Stanislaus River are expressed as population rates (e.g., survival, fecundity, and offspring per adult female). In the absence of density-dependent factors, the productivity parameters measure the ability of salmon to survive to reproduce and reproductive success (McElhany et al. 2000).

Desirable population growth rates are commonly determined by identifying an abundance target and a date in the future by which that abundance should be attained (e.g., NMFS 2012a). The population growth rate is then calculated as the minimum population growth needed to achieve the desired abundance in the pre-determined timeframe. However, this approach does not always result in productivity estimates that reflect healthy populations. An example of this would be if the abundance target could be achieved in less time by a population displaying growth rates typical of the species as a whole.

While population growth rates vary depending on environmental conditions, demographic conditions, and how abundance relates to local habitat carrying capacity, species are often characterized as having "intrinsic" population growth rates that reflect their life-history and demographic characteristics (e.g., age at first reproduction, fecundity, survival, and sex ratio). The reproductive success rates and life-stage specific survival rates observed in other viable salmonid populations, in the absence of density-dependent limitations, are valid reference points for determining adequate productivity goals and targets for managed populations. The

SEP group recognizes that these target population growth rates (and their component vital rates) may not be achieved when abundance levels approach the carrying capacity of the habitat because density-dependent effects may reduce survival rates, as described by "intrinsic productivity" by McElhany et al. (2000).

3.4 Spatial Structure

Spatial structure refers to the geographic distribution of populations or individuals in a population. McElhany et al. (2000) suggest that a population's spatial structure is made up of the geographic distribution of individuals in the population and the processes that generate that distribution. The structure of a population depends on the quality of habitat available to the population, how the habitat is configured spatially, the dynamics of the habitat, and the dispersal characteristics of individuals in the population (McElhany et al. 2000).

Fresh et al. (2009) point out that spatial structure helps contribute to population persistence by: 1) reducing the chance of a catastrophic loss because groups of individuals are widely distributed spatially; 2) increasing the chance that locally extirpated or dwindling groups will be rescued by re-colonization; and 3) providing more opportunity for long-term demographic processes to buffer a population from future environmental changes. Rosenfield (2002) found evidence among North American fishes of an interaction of species' geographic extent and mean body size on extinction risk.

Fullerton et al. (2011) evaluated the spatial structure of Chinook salmon populations in the lower Columbia River. They concluded that protecting or restoring areas that can support large source populations would increase the overall stability of spatially structured populations (i.e., metapopulations) by increasing the number of individuals available to increase the size of, or recolonize, nearby populations.

The SEP group discussed how to apply the spatial structure parameter to the Stanislaus River and San Joaquin River basin, given the background information discussed above and considering the general guidelines developed by McElhany et al. (2000). The SEP group focused on establishing environmental objectives that would support a source population in the Stanislaus River. Attaining this biological outcome would contribute directly to the system-wide spatial structure objectives for Chinook salmon and steelhead throughout the

Central Valley (NMFS 2014).

4 CURRENT STATUS OF CHINOOK SALMON AND STEELHEAD IN THE SAN JOAQUIN RIVER BASIN

A general overview of the current status for the biological objectives relative to their historical status was developed and is presented below.

4.1 Fall-run Chinook Salmon

Historical records made by Spanish explorers in the early 1800s and later that century by John Muir, Livingston Stone, and others suggest that fall-run Chinook salmon were historically abundant throughout the San Joaquin River basin (Yoshiyama et al. 1996). As European settlement occurred in the area, salmon runs diminished due to habitat degradation and loss. According to a report by the Stanislaus River Fish Group, hydraulic mining likely caused the initial decline of Chinook salmon and steelhead runs in the Stanislaus River (SRFG et al. 2003). These early dams were small, temporary, and only partial impediments to movement.

While spring-run Chinook salmon were believed to be the primary salmon run in the Stanislaus River, fall-run Chinook salmon also historically inhabited the river and became dominant following construction of Goodwin Dam, which blocked upstream migration between 1913 and 1929 (Yoshiyama et al. 1996). Today, though not a state- or federally-listed species, fall-run Chinook salmon populations across the Central Valley are also severely impacted and vulnerable to extinction (Katz et al. 2012).

Production of fall-run Chinook salmon in the San Joaquin River basin often falls to very low levels (USFWS 2001). Factors limiting their viability in the San Joaquin River basin include, but are not limited to, low flows, lack of rearing habitat, hatchery practices resulting in reduced fitness and genetic diversity, and predation. Fall-run Chinook salmon production counts for the Stanislaus River averaged 10,868 fish from 1967 to 1991 (SFWO 2014). This value forms the basis for judging progress made toward reaching the goal of producing 22,000 fish in this river to help achieve the goal of doubling fish production from the Central Valley. Adult fall-run Chinook salmon escapement into the Stanislaus River averaged 3,087 fish from 2003 to 2013 (Gutierrez 2014).

Fall-run Chinook salmon life-history diversity is believed to be constrained on the Stanislaus River. Caswell rotary screw trap data on fall-run Chinook salmon size and date-at-migration reveal that, in many years, half of the smolt phenotype migrates within a period of less than 3 weeks period, and at least some smolt migrants are detected when temperatures or other conditions in the lower San Joaquin River may be inhospitable (e.g., after early June; Table 6). Similarly, 50% of parr-sized fish pass Caswell in a period that is almost always less than 1 month (Tables 6 and 8). Furthermore, in several years a small percentage of juvenile migrants are parr or smolt-sized fish, whereas in other years (years when juvenile production is low), larger sized migrants represent the vast majority of all juveniles detected at Caswell (Johnson 2014). This constriction means that juvenile migrants are not experiencing conditions in the lower San Joaquin River, Delta, Estuary and nearshore ocean environments across the full range of dates during which they might capitalize on optimal conditions. This high inter-annual variation in size-at-migration is believed to reflect a lack of suitable rearing conditions on the Stanislaus River.

4.2 Spring-run Chinook Salmon

Historically, spring-run Chinook salmon occurred in the headwaters of all major river systems in the Central Valley, where natural barriers to migration were absent (NMFS 2014). This habitat was estimated to have supported runs as large as 500,000 fish between the late 1880s and 1940s (Yoshiyama et al. 2001; CDFG 1990). Although spring-run Chinook salmon were probably the most abundant salmonid in the Central Valley under historical conditions, large dams eliminated access to almost all historical habitat (Figure 5) and the run has suffered the most severe declines of any of the four Chinook salmon runs in the Sacramento River basin (Fisher 1994).

Before the construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River (Fry 1961). For many decades, spring-run Chinook salmon were considered to be extirpated from the San Joaquin River basin (Fisher 1994). More recently, there have been reports of “spring running” Chinook salmon in San Joaquin tributaries, including the Stanislaus and Tuolumne rivers (NMFS 2013a), which suggests there is existing potential for spring-run Chinook salmon to recolonize and persist in the Stanislaus River. In addition, in 2014, a reintroduction program was initiated as part of the San Joaquin River Restoration Program, and 54,000 juvenile spring-run Chinook salmon were released into the river.

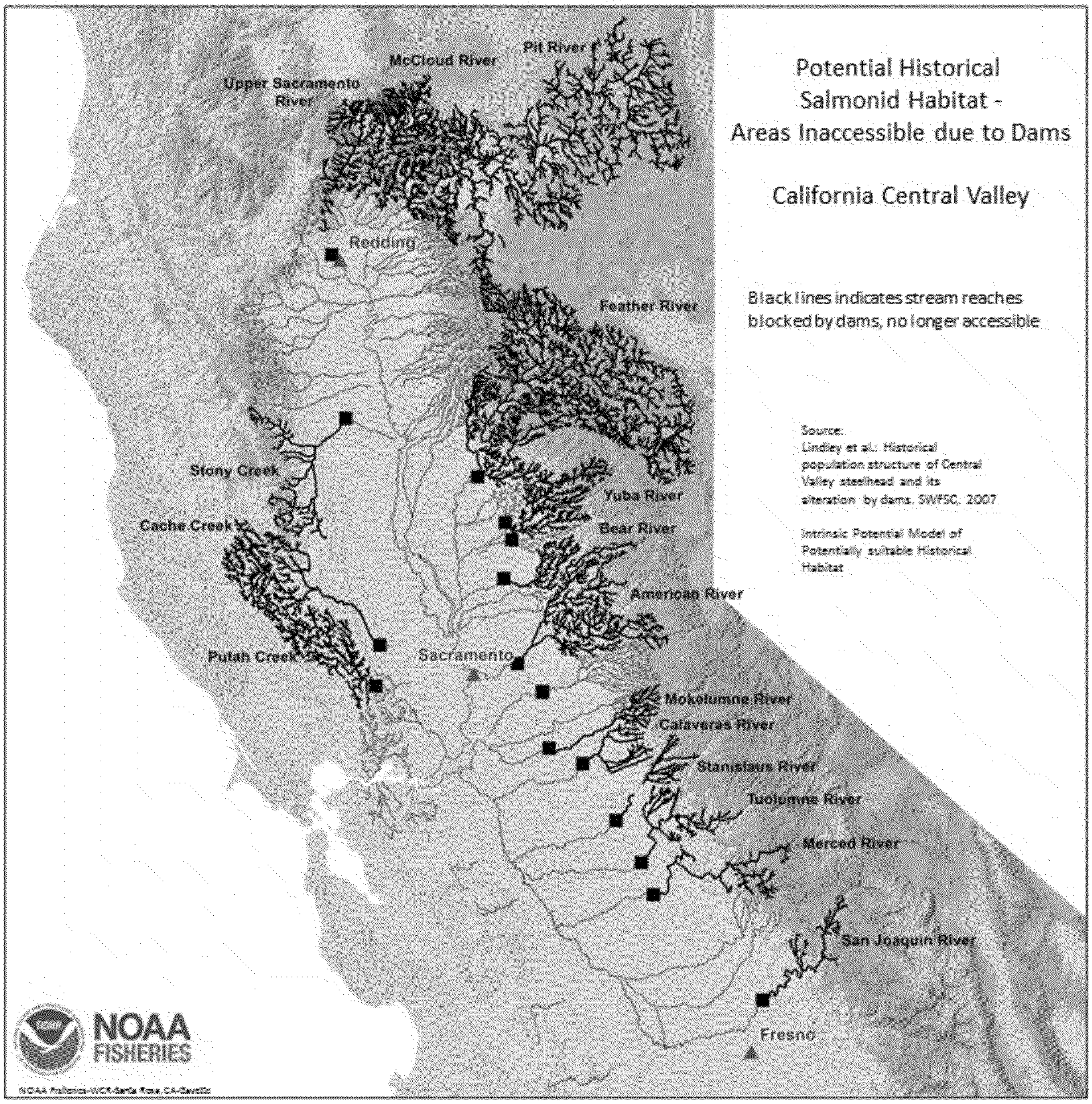


Figure 5
Dams that Currently Block Access to More than 90% of Historical Spawning and Rearing Habitat of Chinook Salmon and Steelhead in the Central Valley

4.3 *O. Mykiss* (Steelhead and ResidentRainbow Trout)

Historically, steelhead were found from the upper Sacramento and Pit rivers south to the

Kings River and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (Yoshiyama et al. 1996). Lindley et al. (2006) estimated that there were at least 81 steelhead populations distributed primarily throughout the eastern tributaries of the Sacramento and San Joaquin rivers. Presently, dams block access to 80% of historically available habitat, and all spawning habitat for about 38% of historical populations (Lindley et al. 2006).

In the San Joaquin River today, steelhead are rare (McEwan 2001). Steelhead were once thought to be extirpated from the San Joaquin River system. However, Zimmerman et al. (2009) found evidence for steelhead presence in all three San Joaquin River tributaries, but their methods could not provide estimates of abundance. Monitoring has also detected small populations of non-hatchery origin steelhead in the Stanislaus River and other streams previously thought to be devoid of steelhead (McEwan 2001). In essence, steelhead are found in most Central Valley watersheds where people have made a concerted effort to look for them. A total of 23 *O. mykiss* larger than 406 mm (16 in) in length returned to the Stanislaus River from 2003 to 2011 based on weir counts data files distributed regularly by FISHBIO, although no sampling was conducted during spring for 2 years during this period (2006 and 2008).

An issue associated with estimating steelhead abundance is the difficulty in distinguishing anadromous fish from the resident form of *O. mykiss* that have matured in the river. Also, due to their large size and strong swimming abilities, juvenile steelhead are rarely captured in the rotary screw traps (RSTs), such as the one located at RM 8 near Caswell State Park. It is unclear at this time whether this lack of catch is due to the scarcity of smolts produced in the river, the known poor efficiency of RSTs at catching large juvenile steelhead, steelhead outmigration timing being outside the RST monitoring period, or some combination of the three possible factors.

The resident *O. mykiss* population of the lower Stanislaus River is relatively abundant compared to the rare anadromous form. These stream-maturing and permanent river residents are most abundant in the cold, gravel-bedded reach from Goodwin Dam to Oakdale, and support a popular sport fishery. They are typically found in areas with high to moderate water velocity, and some type of structure or cover, such as boulders or cobble, large wood, or aquatic vegetation. Demographic information on the population, such as total abundance, age structure, and productivity, are largely unknown. One recent study by Bergman et al. (2014) estimated the total population of *O. mykiss* in the reach extending from the base of Goodwin Dam to 200 meters downstream at about 3,400 fish. Captures of *O. mykiss* labeled as adults in the Oakdale rotary screw traps shows fish in this stage ranging from 300 mm FL to 475 mm FL. Records of *O. mykiss* caught at the weir have identified residents up to 550 mm FL, though most are in the 300- to 500-mm FL range.

4.4 Late Fall-run Chinook Salmon

Recent adult salmon weir counts in the Stanislaus River have documented small numbers of Chinook salmon migrating upstream in January, February, and March. Yoshiyama et al. (1996) mention that late fall-run Chinook salmon possibly occurred in the San Joaquin River (based on CDFW reports of late-fall-run fish).

Although the SEP group did not address the issue of targets or goals for late fall-run Chinook salmon, the SEP group recognizes the importance and potential value of diversity in timing of adult migrations, especially in light of the potential effects of projected climate change on environmental conditions.

5 CURRENT STATUS OF STANISLAUS RIVER HABITAT

In 2001, the AFRP identified the mainstem San Joaquin River and its tributaries below Mendota Pool as high priority watersheds in need of restoration due to degraded habitat (USWFS 2001).

In terms of watershed area, the Stanislaus River is the smallest of the three major tributaries (Stanislaus, Tuolumne, and Merced rivers) of the San Joaquin River that support Chinook salmon. It is 113 miles long and its watershed covers approximately 1,075 square miles of area (USFWS 2008). The Stanislaus River is extensively dammed and diverted. Currently, only the lower 58 miles of river are accessible to anadromous fish, with access for adults terminating at Goodwin Dam (NMFS 2014).

The habitat currently available to Chinook salmon and steelhead in the Stanislaus River has been severely limited and impacted as a result of human activities over the past 100 years. As discussed above, the spring-run Chinook salmon ESU is currently considered to be extirpated from the watershed and populations of steelhead are present, but in low numbers. Key stressors to Chinook salmon and steelhead in the Southern Sierra Nevada Diversity Group have been identified in the Central Valley Chinook Salmon and Steelhead Recovery Plan (Appendix A of NMFS 2014). These stressors include but are not limited to the following:

- Passage barriers including Goodwin, New Melones, and Tulloch dams that have led to the loss of access to 80% of the historical spawning and rearing habitat of salmonids in the Stanislaus River watershed
- Low-flow conditions that affect adult immigration into the Stanislaus River by its effect on attraction and migratory cues
- Physical habitat alteration associated with a limited supply of instream gravel and woody debris, leading to poor habitat suitability and low spawning habitat availability
- Flow fluctuations, particularly during flood releases from storage reservoirs, that affect spawning and embryo incubation
- Flow-dependent habitat availability that affects juvenile Chinook salmon and steelhead rearing and outmigration conditions
- Changes in hydrology and channel morphology (e.g., reduced instream gravel recruitment, reduced channel complexity, and increased habitat for predators) that

affect juvenile rearing and outmigration conditions

- Loss of riparian habitat, floodplain and side-channel habitat, and instream cover that affects juvenile rearing and outmigration conditions

In addition, the river section below Goodwin Dam has been identified on the U.S. Environmental Protection Agency (USEPA) Clean Water Act Section 303(d) list for not meeting water quality standards for diazinon, chlorpyriphos, Class A pesticides, unknown toxicity, mercury, and temperature (USEPA 2011). These stressors may possibly play a role in the overall growth and survival of Chinook salmon and *O. mykiss*.

However, the Stanislaus River still provides valuable spawning, holding, and rearing habitat for fall-run Chinook salmon and steelhead (NMFS 2004). Spawning is focused in a reach of river with extensive gravel beds located between the towns of Riverbank and Knights Ferry. Approximately 95% of all fall-run Chinook salmon spawning in the Stanislaus River occurs between Orange Blossom Road and Knights Ferry (Figure 2; NMFS 2009b). *O. mykiss* are commonly observed in the upper reaches of the Stanislaus River between Goodwin Dam and Knights Ferry, with most of these believed to be resident fish. The canyon reach below Goodwin Dam contains little habitat for *O. mykiss*, as this stretch has low velocities, little or no gravel or other in-stream structures such as logs or boulders, and likely limited food production. There are some reaches with faster velocities, gravel- to boulder size substrate, and/or vegetation on the bottom, and these are the habitats where the few *O. mykiss* that are observed in this reach of river are typically found.

Compared to historical conditions, the area of suitable salmonid spawning and rearing habitats has been substantially reduced due to anthropogenic influences including dam construction, in-river aggregate mining, and the conversion of floodplain habitat for agricultural uses (Kondolf et al. 2001; Yoshiyama et al. 2001; Lindley et al. 2006). Along most of the lower Stanislaus River, agricultural and urban encroachment has separated the river from its floodplain. As a result, the channel is incised, which prevents the river from developing and maintaining shallow spawning and rearing habitats necessary for salmonids (NMFS 2014).

Restoration actions conducted to date have included augmenting spawning gravel and supplementing Stanislaus River flows using authority and funding under the CVPIA (NMFS 2014). However, additional restoration work is needed to replenish gravel lost due to mining and dams and provide additional floodplain habitat to replace that which has been lost due to the flattening of the hydrograph (USFWS 2008). In particular, the need for increased freshwater flow rates and rearing habitat during key seasons to support abundance (production) targets for this watershed and the San Joaquin River basin in general is well-studied (e.g., CDFG 1987; AFRP 2005; TBI and NRDC 2010).

6 DEVELOPMENT OF GOALS AND OBJECTIVES SPECIFIC TO THE STANISLAUS RIVER

6.1 Overall Approach

Most previous Central Valley goals and objectives for Chinook salmon and *O. mykiss* are expressed in terms of target abundances (Section 2.3.1). However, the SEP group determined that it was inappropriate to set abundance targets for the Stanislaus River alone, because many factors limit each life stage throughout the entire life cycle of Chinook salmon and steelhead, and many of the factors that affect overall abundance occur outside of the spawning and rearing habitat of the Stanislaus River. Examples of this include predation in the Delta and ocean harvest. Instead, goals the SEP group developed (Plan Phase 1 Goals) reflect improvements that could be attained within the geographic and policy scope described in Section 2.3. The Plan Goals are intended to contribute to all of the Central Valley goals (e.g., CVPIA doubling, CDFG code, and ESA recovery), although they do not specify attainment of a target abundance. Similarly, because establishment and maintenance of viable and healthy populations of Chinook salmon and steelhead in the Stanislaus River contribute to the Central Valley goal of improving spatial structure for each species addressed in this report, there was no need to set Plan Goals and objectives for spatial structure. Thus, the Plan Goals do not directly address the VSP parameters of abundance and spatial structure.

Plan Goals for each of the species and runs discussed were identified that would improve and maintain the VSP parameters of diversity and productivity (i.e., population growth rates as affected by survival rates). One of the biological goals identified was to support the fullest expression of salmon and steelhead life-history diversity to increase population stability, resilience, and productivity. Also, for Chinook salmon populations, productivity goals were described in three phases: 1) attain juvenile survival rates that allow for population growth; 2) attain juvenile survival rates that allow for rapid re-attainment of system-wide population objectives after years with low escapement; and 3) attain juvenile survival rates that reflect those typical among other Chinook salmon populations across the west coast.

The specific biological and environmental objectives developed to help achieve the Central Valley goals and objectives and Plan Goals varied among the species and runs. Also, they were designed to be measurable and monitored over time. Tables 1a and 1b and Tables 1c through 1e provide a summary of the biological objectives for Chinook salmon and steelhead, respectively. In the following sections, the specific metrics associated with each biological objective needed to achieve the Central Valley goals and objectives are defined, and the rationale and approach for each metric is described.

Table 1a

Chinook Salmon Biological Objectives – Productivity and Genetic Objectives

Objective		**Productivity[A]**													**Genetic**	
Life-History Stage		**Juvenile (A)**			**Juvenile (B)**			**Juvenile (C)**			**Adult**				**Adult**	**Egg/Juvenile**
Description	**Briefly**	Juvenile survival rate consistent with population growth rate of 2x over three generations (CRR=1.26)			Juvenile survival rate consistent with population resilience (CRR=2.5)			Juvenile survival rate in freshwter typical of chinook salmon populations across the pacific coast (10%)			Survival/reproductive success of adult migrants				Maintain wild run genetic integrity	
	Achieved By When?	Year 10			Year 15			Year 24			<u>*TBD*</u>	<u>*TBD*</u>	<u>*TBD*</u>	<u>*TBD*</u>	<u>*TBD*</u>	Whenever Spring-running fish are present
	Measure What?	Survival from/to	Survival from/to	Survival total	Survival from/to	Survival from/to	Survival total	Survival from/to	Survival from/to	Survival total	Survival from/to	Egg viability/ deposition	Redd viability	Egg-emergence survival of surrogates	Percentage hatchery origin spawners	Introgression
	Measured Where?	Spawning-to-Caswell [1]	Caswell-Vernalis [1]	Freshwater [2]	Spawning-to-Caswell [1]	Caswell-Vernalis [1]	Freshwater [2]	Spawning-to-Caswell [1]	Caswell-Vernalis [1]	Freshwater [3]	Caswell - spawning grounds at onset of spawning [4]	Spawning grounds	Spawning grounds	Spawning grounds	Spawning grounds	Spawning grounds
Fall-Run	**Wet**	15.00%			18.00%			35.00%			<u>*TBD*</u>	<u>*TBD*</u>	<u>*TBD*</u>	<u>*TBD*</u>	<20% of spawners	<2% inter-run mating
	Median	9.94%	68.41%	2.13%	13.08%	73.18%	4.22%	25.10%	79.70%	10.00%						
	Dry	5.00%			9.00%			15.00%								
Spring-Run	**Wet**	15.00%			18.00%			35.00%			≥ 90%	<10% of female carcasses Retain ≥10% of eggs	≥90% remain intact through incubation period	(>35%)[5]	NA	<2% inter-run mating
	Median	9.94%	68.41%	2.13%	13.08%	73.18%	4.22%	25.10%	79.70%	10.00%						
	Dry	5.00%			9.00%			15.00%								

Notes:

[A] Juvenile productivity and life-history objectives refer only to those fish that migrate before temperatures in the mainstem San Joaquin reach 25°C.

[1] Survival from Spawning-to-Caswell is premised on attainment of Caswell-Vernalis survival rate. If median Caswell-Vernalis survival rate is unattainable, or exceeded, the Spawning-to-Caswell survival rate objective will be adjusted accordingly.

[2] For reference purposes. Includes through-Delta survival. Conditions on the San Joaquin and its tribs affect Delta survival; however, responsibility of San Joaquin tributaries for through-delta survival outcomes is yet to be determined. Improvement in freshwater survival rates assumes river survival rates and Delta survival rates will improve proportionately from current levels.

[3] For reference purposes. Assumes through-Delta survival of 50%—in this case the improvement in river and Delta environments is no longer proportionate as adherence to the proportionate improvement standard would require median survival of >50% in the Delta—there was no consensus that survival rates of >50% in the Delta could be achieved.

[4] Currently, adult survival objectives are only developed for spring-run fish after they have migrated past Caswell. This reflects desired outcomes in the ability of spring-run to successfully "hold" in the river through the summer. Adult survival objectives may be developed (and potentially for fall run and steelhead) in the mainstem San Joaquin; however, those objectives would be part of basin-wide planning and may require adult migration monitoring in the lower San Joaquin.

[5] This objective will be refined to include optimal egg-emergence survival. This is considered a base, applicable in the near-term as a boundary to detrimental conditions.

“>” = greater than

“≥” = greater than or equal to

“<” = less than

CRR = cohort replacement rate

TBD = to be determined

Table 1b
Chinook Salmon Biological Objectives – Life-History Diversity Objectives

Objective		Life-History Diversity (Migration Timing) [A]				Life-History Diversity (Age Class Distribution Minima) [A]	
Description	Briefly	Support range of juvenile migration dates to maintain life history diversity				Support range of sizes at juvenile migration dates to maintain life-history diversity	
	Achieved By When?	Year 10	Year 10	Year 10	Year 10	Year 12	Year 12
	Measure What?	Detection every week no later than…	Detection every week through at least…	Detection every week no later than…	Detection every week through at least…	Minimum % juvenile migrants annually (wetter years)	Minimum % juvenile migrants annually (drier years)
	Measured Where?	Caswell RST	Caswell RST	Mossdale RST	Mossdale RST	Caswell RST	Caswell RST
Fall-Run	Fry	Last week of January	2nd week of April	N/A	N/A	20%	20%
	Parr	1st week of February	Last week of May	2nd week of February	1st week of June	20%	30%
	Smolt	3rd week of February	1st week of June	Last week of February	2nd week of June	10%	20%
Spring-Run	Fry	1st week of January	2nd week of April			20%	20%
	Parr			TBD	TBD	20%	30%
	Smolt					10%	20%
	Yearling [1]	Detection in ≥50% weeks Oct-Jan	Detection in ≥50% weeks Feb-April	TBD	TBD	≥1.5 yearlings per 1,000 female spawners	

Notes:

[A] Juvenile productivity and life history objectives refer only to those fish that migrate before temperatures in the mainstem San Joaquin reach 25°C.

[1] The yearling life-history strategy is associated with spring-running adults (fall-run adults may produce yearlings as well, but it is considered to be extremely rare). Production of some yearlings is expected whenever spring-run Chinook reproduce successfully, however, detection of yearlings is only required when sufficient numbers of spring-run salmon reproduce—see tech memo for calculations and discussion related to when yearling detection is expected.

"≥" = greater than or equal to

N/A = not applicable

RST = rotary screw trap

TBD = to be determined

Table 1c
Steelhead Biological Objectives – Productivity Objectives

Objective		Productivity						
Life-History Stage		Juvenile (A)		Juvenile (B)		Juvenile (C)		Adult
Description	Briefly	Smolt size - proportion of smolts (stages 4 and 5) observed should be of a size able to survive the ocean phase and return as anadromous adults		Smolt production - naturally produced smolts (stages 4 and 5) per female spawner increase to levels consistent with other healthy steelhead populations….		Smolt survival - smolt (stages 4 and 5) survival rate consistent with population resilience		Egg survival consistent with….
	Achieved By When?	TBD		TBD		TBD		
	Measure What?	Fork Length		Number of smolts per female spawner		Survival through lower Stanislaus River		Egg survival
	Measured Where?	TBD (Caswell Area)		Caswell (or other location prior to confluence with mainstem)		Lower end of gravel bedded reach	Delta entry	
Steelhead		At least 90% of the smolts (stages 4 and 5) observed should be 150 mm (5.9 in) fork length or greater in length		Naturally produced smolts (stages 4 and 5) emigrating from the river each year shall increase to at least 165 per female spawner		>90%		>35%
		Fork length	150 mm (5.9 in)	3-year running average				
		Percentage	90%					
		Year type	All years	Minimum	165			

Notes:
">" = greater than
mm = millimeter

in = inch
TBD = to be determined

Table 1d
Steelhead Biological Objectives – Productivity Monitoring Objectives

Objective		Productivity	
Life-History Stage		Juvenile (A)	Juvenile (B)
Description	Briefly	Monitoring density (A) - observe densities that...	Monitoring growth rates (B) - ...
	Achieved By When?	TBD	TBD
	Measure What?	Parr/km	Growth in mm/day (in/day)
	Measured Where?	Stanislaus River	
Steelhead		The density of age-0 (measured in the summer) *O.mykiss* shall increase over time to a minimum of one (1) individual on average, per square meter or 20,000? per river km, on average	Age-0 and age-1 *O. mykiss* increase over time to 0.60 mm/day (0.02 in/day) (averaged over an entire season)

Notes:
km = kilometer
mm = millimeter
in = inch
TBD = to be determined

Table 1e
Steelhead Biological Objectives – Life-History Diversity Objectives

Objective		Life History Diversity (Anadromy)				
Life-History Stage		Juvenile			Adult	
Description	Briefly	Smolts produced per female spawner	Supports anadromy via a sufficient proportion of	Supports a range of outmigration dates for	Support viable levels of both life-	Support viable levels of both life-

n		indicative of healthy spawner…		juveniles with anadromous *O. mykiss* mothers	life-history diversity	history types	history types
	Achieved By When?	TBD		TBD	TBD	TBD	TBD
	Measure What?	Smolts/ female spawner		Proportion of age-0 juveniles with anadromous maternal origin in otolith	Smolt (stage 4 and 5; at least 150 mm [5.9 in] fork length) Detection	Proportion of adult *O. mykiss*	Resident adult abundance
	Measured Where?	Spawning reach		Age-0 *O. mykiss* collected in rearing areas	Caswell rotary screw trap		Reach just downstream of Goodwin Dam
Steelhead		This shall be tracked on a brood year basis					Age 1+ fish superpopulation >1,492 to 7,873
		Good water years	>300	>45%	Minimum of 4 months of the year	>25% resident - Summer	3 to 9 age 1+ fish per 100 m^2 (1,076 ft^2)
		Poor water years	>150			>20% anadromous - immigrating adults	

Notes:
“>” = greater than
ft^2 = square feet
m^2 = square meter
mm = millimeter
TBD = to be determined

6.2 Fall-run Chinook Salmon

6.2.1 What is the Problem?

The production[1] of San Joaquin fall-run Chinook salmon in its three salmon-bearing tributaries, the Stanislaus, Tuolumne, and Merced rivers, often falls to very low levels, with low spawning escapements related to drought conditions and higher (but still sub-par) escapement generally following years with high spring runoff (USFWS 1995). Abundance has generally declined since the 1967 through 1991 period used to set AFRP ocean production objectives. Actual fall-run Chinook salmon counts in the Stanislaus River (escapement) are variable and averaged 3,087 fish from 2003 to 2013 (Gutierrez 2014). Juvenile survival rates are generally low for this population (AFRP 2005); current estimates of total freshwater survival of Stanislaus fall-run Chinook salmon are extremely low (less than 2%; Appendix A) and are expected to result in further population decline. Productivity is further impacted by impediments to efficient adult migration and holding in the San Joaquin River basin. Life-history diversity of the fall-run Chinook salmon population is constrained throughout the Central Valley (Lindley et al. 2009; Miller et al. 2010; Carlson and Satterthwaite 2011) and in the Stanislaus River, in particular, by numerous factors. These factors include inadequate habitat to retain rearing juveniles during high-flow events and high water temperatures, particularly in late spring of dry years, which results in selection pressures against later (larger) migrants. Also, the influence of hatchery-produced spawners on the Stanislaus River fall-run Chinook salmon population (Kormos 2012 et al.; Plamer Zwalen and Kormos 2013) is well-above limits indicative of healthy populations, suggesting that population viability is compromised by hatchery stocks (Araki et al. 2007; Lindley et al. 2007; Johnson et al. 2012). The spatial distribution of fall-run Chinook salmon spawning habitats within the San Joaquin River basin is not a primary concern, as fall-run Chinook salmon spawn in each of the San Joaquin River's main tributaries and are being restored to the San Joaquin mainstem.

6.2.2 What Outcome(s) (Central Valley Goals) Will Solve the Problem?

Abundance. Abundance goals for fall-run Chinook salmon are set by state and federal law for the Central Valley, including the San Joaquin River and its three salmon-bearing

[1] As used here, "production" means the number (abundance) of fish available to the ocean fishery: 2-year-old salmon in the ocean. This term should not be confused with "productivity," which refers to population growth rates and/or the population vital rates (e.g., survival, fecundity) that determine population growth rate.

tributaries. The CVPIA (Section 3406 of the CVPIA, Title 34 of Public Law 102-575) calls for naturally spawning populations of anadromous fish that are double the 1967 to 1991 baseline, within 10 years. State law (CDFG Code § 6902(a)) and water quality regulations (SWRCB 2006) express the same target.

Productivity and Life-history Diversity. Improvements in fall-run Chinook salmon productivity (measured as juvenile survival and adult migration success in freshwater) and increased life-history diversity (i.e., size at and timing of juvenile migration) are necessary to achieve several objectives. These objectives include abundance targets for fall-run Chinook salmon in the Central Valley (USFWS 2001), maintaining fish "in good condition" (CDFG Code § 5937), and achieving acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (Lindley et al. 2007). The objectives are also consistent with all known fisheries-related management policies.

Genetic Diversity. For fall-run Chinook salmon, concerns about the level of genetic diversity needed to support a healthy and viable population revolve around the influence of hatchery production and management (Williams 2006). A high occurrence of straying of fall-run Chinook salmon occurs between the San Joaquin and Sacramento basins (Johnson et al. 2012; Kormos et al. 2012), potentially due to the relative outflows during the return migration, as well as hatchery release practices (Marston et al. 2012). However the extent to which hatchery fish are functioning to sustain San Joaquin salmon populations has gone largely undetected until recently (Johnson et al. 2012; Kormos et al. 2012). The need to reform the hatchery practices system-wide has been identified by scientists and policymakers based on growing concerns and scientific findings about the potential effects of hatcheries on the viability of salmon and steelhead in their natural habitats. In 2010, the U.S. Congress established and funded a hatchery review process in California due to concern that the genetic resources required to support a sustainable salmon fishery and recover at-risk runs of salmon were not being adequately managed using traditional hatchery practices (HSRG 2012).

Concerns about the level of genetic diversity needed to support a healthy and viable population also relate to the amount of introgression with spring-run Chinook salmon. Eliminating genetic introgression with spring-run Chinook salmon or reducing it to a very low level, is a major goal for the maintenance and restoration of fall-run Chinook salmon in the Central Valley (Lindley et al. 2006; HSRG 2014). Thus, providing opportunities for fall run reproductive isolation is particularly important for the maintenance of fall-run populations in rivers with dams that cause spring-run and fall-run Chinook salmon to spawn in the same area.

6.2.3 What Does Solving the Problem Look Like (Central Valley Objectives)?

Abundance. The AFRP calculated Chinook salmon production levels for each Central Valley river that would be consistent with the Central Valley-wide goals of the CVPIA. The AFRP objective for ocean production of fall-run Chinook salmon for the three salmon-bearing tributaries in the San Joaquin River basin is 78,000, divided among the Stanislaus (22,000), Tuolumne (38,000), and Merced (18,000) rivers (USFWS 2001). The SEP group used the AFRP target for natural production of fall-run Chinook salmon (22,000) as a Central Valley objective to set a context for determining environmental objectives (e.g., physical, chemical, and biological conditions necessary to support juvenile rearing) for the Stanislaus River that will be necessary to support fall-run Chinook salmon restoration in the Central Valley. The SEP group recognized that attainment of this Central Valley objective requires adequate conditions throughout the fish's life cycle. The group also recognized that abiotic and biotic conditions in the Stanislaus and lower San Joaquin rivers must support, but may not be entirely sufficient, to result in attainment of this objective, because this also depends on conditions affecting Chinook salmon and steelhead while migrating through the Delta and rearing in the Pacific Ocean. Therefore, abundance, per se, is not a Plan Goal, and no specific abundance target was established as a biological objective for fall-run on the Stanislaus River.

Productivity. The AFRP and CVPIA provide guidance regarding the desired rate of population growth for fall-run Chinook salmon: doubling from a baseline within 10 years (roughly three Chinook salmon generations). Also, the AFRP and CVPIA targets call for natural population growth rates that make populations resilient against periodic cohort failures (Johnson et al. 2010). Specifically, the CVPIA and AFRP measure production as a 5 year average—the implication of this is that populations may fluctuate above and below the production target, but they should be resilient such that periodic years of low production, due to any cause, do not prohibit re-attainment of an abundance target in the next generation.

These two elements of the AFRP/CVPIA Central Valley production objectives were used to develop Plan Goals and biological objectives for productivity (i.e., survival) rates on the Stanislaus River. Furthermore, just as the Central Valley objective for the production of Stanislaus River fall-run Chinook salmon was not categorized by the SEP group as a biological objective for the Stanislaus River, neither does that target represent a limit on the improvements in survival necessary to restore this population. Abundance and productivity are different attributes of viability, and calculating a population growth rate that will lead to a particular abundance in a pre-determined timeframe is not the same as estimating that population's intrinsic population growth rate ("r"). Rather, the SEP group looked to other viable populations of Chinook salmon to gauge freshwater survival rates that would characterize a restored Chinook salmon population on the Stanislaus River.

Life-history Diversity. No policies speak directly to Central Valley objectives for necessary improvements in the life-history diversity of fall-run Chinook salmon. However, there is increasing evidence that habitat loss and simplification has constrained fall-run Chinook salmon life-history strategies and improvements will be necessary to attain the Central Valley goals for this run of Chinook salmon (Lindley et al. 2009; Miller et al. 2010; Carlson and Satterthwaite 2011; Satterthwaite et al. 2014; Schindler et al. 2010; Ruckelshaus et al. 2002).

Genetic Diversity. Benchmark metrics have been established based on genetic models to reduce the proportion of hatchery-origin spawners (pHOS) in Central Valley rivers to less than 20% of adult spawners, and preferably less than 5%, even when the hatchery of origin is a conservation-orientated facility using best management practices. A high proportion of hatchery-origin spawners has the potential to increase competition for spawning habitat, reduce reproductive success, and erode mechanisms required for local adaptation of salmon to their environment and ultimately puts them at a high risk of extinction (Lindley et al. 2007; Araki et al. 2007).

Specific gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations in the Central Valley (Lindley et al. 2007; HSRG 2014).

6.2.4 How Much Will this Effort Contribute to Attainment of these Central Valley Objectives (Plan Goals)?

Abundance. As described, no abundance targets, per se, were set as Plan Goals for the Stanislaus River population of fall-run Chinook salmon. However, AFRP production (abundance) targets were used to set context for Plan Goals and biological objectives for fall-run Chinook salmon survival rates (productivity) in the Stanislaus River. In addition, Central Valley objectives for natural production imply in-river escapement targets; thus, the escapements implied by the Central Valley production objectives were used to guide development of environmental objectives discussed below (e.g., the need to provide adequate habitat for a given number of fish).

Productivity. As described, the Central Valley goals and objectives were used to guide development of Plan Goals for productivity (freshwater survival rates). Plan Goals and biological objectives for freshwater survival are expected to result in sustainable CRRs. These productivity goals become more protective progressively over time, to achieve freshwater survival rates sufficient to generate:
Population growth rates consistent with the Central Valley goal of increasing the population by two-fold in three generations

1. Population resilience, represented by freshwater survival rates needed to re attain production targets within one generation, following periods of low production
2. Freshwater survival rates that are typical of other self-sustaining populations of ocean-type Chinook salmon

The SEP group understands there will be density-dependent effects and acknowledges that productivity will decrease as the Stanislaus River approaches carrying capacity. While the exact point where productivity will decrease as spawners increase is unknown, the level may range from 4,000 to 6,000 fish, and may also be exacerbated during dry year conditions. Therefore, the SEP group will refine productivity objectives as needed as spawner populations increase. The SEP group also acknowledges that it would be extremely difficult or impossible to achieve freshwater survival targets without improvement in both the river and Delta environments; the necessary improvements in overall freshwater survival that were identified were distributed across riverine and estuarine habitats.

Life-history Diversity. The SEP group also identified Plan Goals for life-history diversity that must be met to achieve a self-sustaining population of naturally produced fall-run Chinook salmon in the Stanislaus River. Life-history diversity must be maintained to a level that allows Chinook salmon populations to respond to varying climatic, hydrologic, and ocean conditions over time (Beechie et al. 2006; Miller et al. 2010; Satterthwaite et al. 2014; Spence and Hall 2010). The Plan Goal for fall-run Chinook salmon life-history diversity is to support the fullest expression of fall-run Chinook salmon life-history diversity. Attaining the fullest expression will result in increased population stability, resilience, and productivity.

Genetic Diversity. In addition, the SEP group adopted the Central Valley goal for minimizing hatchery influence to allow for adaptation to local conditions and maintain life-history diversity (Lindley et al. 2007; HSRG 2012). It was recognized that hatchery management is a San Joaquin River basin-wide and Central Valley-wide issue in that there are no hatcheries on the Stanislaus River. To the extent that attaining this Central Valley goal relies on actions taken and conditions established within the Stanislaus and lower San Joaquin rivers, the SEP group believed it was important to include the goal within the Stanislaus River scope, to the extent practical.

The SEP group's intent is to create conditions that support restoration of a self-sustaining fall-run Chinook salmon phenotype that contributes to the overall diversity, productivity, abundance, and resilience of Chinook salmon populations in the San Joaquin River basin and the Central Valley as a whole. Establishing and maintaining such a distinct population requires that gene-flow between distinct life-history types be limited. It also requires that environmental objectives support the fall-running phenotype during all life-history stages.

6.2.5 What Suite of Species-specific Outcomes (Biological Objectives) Characterize Success?

Fall-run Chinook salmon are the only species or run of salmon or steelhead addressed by the SEP for which sufficient data exist to calculate current productivity, outmigration timing for different life stages, and potential concerns with genetic diversity. Fall-run Chinook salmon abundance continues to decline on the Stanislaus River, indicating that current population biological attributes are not sufficient to maintain a self-sustaining, viable population, much less to attain the SEP's goals and objectives. The objectives below were developed to achieve the SEP's Plan Goals for the Stanislaus River. All objectives for fall-run Chinook salmon include data specific to the Stanislaus River where available, to allow for comparison between current biological attributes of the fall-run Chinook salmon population and biological objectives that characterize success.

6.2.5.1 Rationale for Productivity Objectives

No single process is responsible for attaining adult escapement/production targets. Juvenile survival rate is the relevant metric to set at the local spatial scale to support attaining a global abundance target. All planning processes must set and achieve biological objectives that are consistent with attainment of escapement/production targets in order to attain desired freshwater survival rates. Currently, survival rates through the Delta appear to be 3.75% (Brandes 2014) and greater than survival rates in-river (Table 2).

Table 2
Estimated Survival Rates for Stanislaus River Salmon from Various Sources

Survival	USFWS (2011)	NMFS (2012a)	Stanislaus River (2013)	Consensus Estimate
In-tributary	6.64%	5.64%	1.6%	1.6%
Tributary-to Delta	----		1.52%	51.33%*
In-Delta	5%	5%		3.75%
To production	2.83%	2.83%	2.83%	2.83%
Post-production	50%	70%	60.11.%	60.11%

Notes:
* This value estimates survival from Caswell to Vernalis as Implied based on estimated upstream survival rate and estimated in-Delta survival rate.
Stanislaus (2013) reflects calculations from data collected at the Stanislaus River RST at Oakdale and Caswell, as reported by USFWS. None of the reference studies estimated survival from the lowest elevation RST to the Delta; the SEP group estimated this value based on an average of survival per river mile upstream of the lowest RST and in Delta.

No historical data are available from this system to establish the appropriate balance between in-river and through-Delta survival and no analogous salmon-bearing river systems with such a large inland estuary exists elsewhere. The SEP group found no reason that survival rates in river should be greater than or equal to through-Delta; thus, the current asymmetry of survival rates (higher survival through the Delta) was left in place. The SEP group adopted an initial allocation of survival rates, based on an equal improvement in survival from current rates in both environments.

The survival rate needed to attain a given abundance target within a pre-determined period is not necessarily the survival rate that reflects healthy productivity of a Chinook salmon population. Indeed, Pacific salmon populations are characterized by high intrinsic rates of growth (Healey 1991; Quinn 2005) that arise from a strategy of placing eggs in low-productivity riverine environments where incubation and juvenile success rates are relatively high. The capacity to quickly colonize new habitats and rapidly rebound from periods of poor recruitment explain, in part, the widespread and long-term success of Pacific salmon. Furthermore, historical accounts from across the Pacific coast of super-abundant spawning runs of Chinook salmon attest to the fact that these populations were probably often limited only by competition for mates and suitable spawning habitats, not survival rates during freshwater juvenile or marine life stages.

As a result, the SEP group adopted biological objectives for juvenile survival in freshwater that increased in phases such that they:

1. Allowed for attaining population growth rates prescribed by Central Valley goals for abundance.
2. Reflected the need for population resilience (again, consistent with Central Valley goals for abundance).
3. Tracked survival rates typical of this species, consistent with the goal of maintaining fish populations in good condition.

At higher levels of survival required to attain sub-goals 2 (population resilience) and 3 (survival rates typical of Chinook salmon in freshwater), the approach of generating "equal improvement" in in-river and through-Delta relative survival rates produced survival rate targets in the Delta that may be unachievable (i.e., they would not meet the S.M.A.R.T. criteria). Through-Delta survival rates were capped at 50% and in-river survival rates were adjusted accordingly to attain desired freshwater survival rates.

Freshwater survival rates in objectives 1 (increase abundance by two-fold in three generations) and 2 (population resilience) assume current post-Delta survival rates through the Estuary and Pacific Ocean. If survival rates in the bay/ocean change substantially, the freshwater survival rate objectives may be adjusted. However, freshwater survival rates for objective 3 are those that are typical of Chinook salmon populations across their range; they reflect adequate "productivity" of a population not constrained by density-dependent effects.

Finally, the SEP group recognizes that survival rates in freshwater may be impacted by density dependent factors when populations approach local carrying capacity. Thus, attainment of the current survival objectives should be measured only when the spawning population is below a certain threshold (McElhany et al. 2000); that threshold remains to be determined.

6.2.5.2 Approach to Productivity Objectives

The SEP group created a spreadsheet based life-cycle model to investigate what changes to current survival rates in different life stages were necessary to attain Plan Goals for population growth rates. Survival rates for various life stages of San Joaquin River basin Chinook salmon were collected from previous reports and existing data sources (Table 2). Where estimates differed among reports, the SEP group determined which estimates were most likely to reflect actual conditions, which is stated as the "Consensus Estimate" in Table 2. Previous studies did not account for mortality between the lowest sampling station on the Stanislaus River (the RST at Caswell) and the Delta, which begins at Vernalis on the San Joaquin River (Figure 3). Survival in this 11.5-river mile stretch was estimated from the per-river-mile average of survival rates upstream of the stretch between Oakdale and Caswell and through the Delta.

To determine what increase in freshwater survival rate would be needed to produce population growth rates that satisfied the SEP group's three phased improvements in productivity, the SEP group assumed that ocean mortality remained constant. Survival in the marine environment was divided into two components. The first was survival from Chipps Island (the sampling station at the western edge of the Delta; Figure 3)[2] to age 2 (the age

[2] This area is often within the freshwater zone, but in the spring of drier years, is a reasonable approximation of the beginning of a migrating smolt's entry into brackish water.

when fish are counted as part of the ocean fishery). Survival through this component was assumed to be 2.8% based on NMFS (2009b). Survival through this marine phase was termed "survival to production." The second component of marine survival reflects commercial and sport fishing pressure in the ocean; estimates for survival through the fishery ("post production") varied and the SEP group used the value for natural production calculated annually in the CVPIA production tracking spreadsheet called chinookprod (available from fws.gov/stockton/afrp/). This estimate (60% harvest mortality) fell between those reported by USFWS (2001) and NMFS (2012a). Total marine survival rates were similar to those (1 to 2%) estimated by Bradford (1995) for Chinook salmon.

These two components of marine survival were considered to be fixed. Even the highest estimated mortality in the commercial and recreational fishery is a small fraction of mortality rates elsewhere in the life cycle (Table 2); thus, changes to fishing pressure would not be expected to change population growth rates substantially compared to the potential for improving survival elsewhere.[3]

A spreadsheet model was used to determine the average freshwater survival rates that were consistent with the desired population growth rates. The SEP group then determined how survival in freshwater would be apportioned between the riverine and freshwater estuarine environments. This distinction was necessary because the two environments are quite different ecologically and are impacted by different water user entities, water extraction methods, and other factors. Because the Estuary is a unique habitat because other salmon spawning rivers do not end in an inland estuary of this size, there is no *a priori* expectation for proportional survival of Chinook salmon through a riverine versus estuarine environment.

The linear distance travelled from Knights Ferry (the estimated centroid of fall-run Chinook salmon spawning on the Stanislaus River; Figure 2) to the Delta is 57 miles, which is approximately the same distance that juvenile salmon and steelhead are required to migrate through the Delta (54.5 miles from Vernalis to Chipps Island), so the SEP group considered targeting equal survival rates to these different environments. However, the SEP group determined that it was reasonable for upstream survival rates to be lower than through-Delta

[3] If ocean salmon fishing pressure changed, this would alter the estimate of necessary freshwater survival rates.

survival rates, because of the naturally higher rates of egg and larval mortality compared to those of older, larger fish. Thus, there was no basis, initially, for expecting a different balance of proportional survival rates in the two environments than what exists currently, and the SEP group maintained the current asymmetry in survival rates between the riverine and estuarine environments (Table 2).

Target survival rates for each environment were determined by increasing current survival rates proportionately (equal improvement), with a upper limit imposed on survival rates at 50%. This upper limit assumes that survival rates greater than 50% in either the riverine or estuarine portion of the freshwater life cycle would be unrealistic. The 50% survival rate limit only affected biological objectives for the Delta, as current Delta survival is greater than survival in-river. The same approach to allocating responsibility for improved freshwater survival rates was employed by NMFS (2013a).

The SEP group used the spreadsheet model to determine what overall freshwater survival rate (x) was necessary, in the context of current marine survival rates, to support the initial desired CRR necessary. The resulting freshwater survival rate was divided by the current, estimated average freshwater survival rate (y) to determine a multiplication factor (z) by which total freshwater survival would need to be improved. Because the SEP group assumed that improvement in survival rates would be equal in both parts of the freshwater environment (riverine and Delta), current survival rates in those two environments were multiplied by sqrt z (because $\mathrm{sqrt}(z)^2 = z$) to determine targeted future survival rates for those environments.

The third and final increment of improvement in population growth rate was intended to result in survival rates that were approximately typical of Chinook salmon across their range. Three reviews of Chinook salmon survival in freshwater across their range were assessed by the SEP group (Healey 1991; Bradford 1995; Quinn 2005). Each study synthesized results of numerous other studies to produce an average survival from egg-to-brackish water entry. In some cases, the same rivers were studied, but the time series used appeared to be somewhat different. Members of the SEP group contacted the authors of these studies to understand the methodologies that were used and to confirm that the populations studied represented "typical" (i.e., not pristine) conditions across the Chinook salmon range.

Against this backdrop, determining in-river survival rates necessary to achieve the three staged productivity goals was calculated using the spreadsheet model (Appendix A). Following are additional descriptions of the biological objectives related to the SEP group's three phased goals for improving productivity of Stanislaus River fall-run Chinook.

6.2.5.3 Productivity Objectives

6.2.5.3.1 Objective A: Median Egg to Caswell Survival Equals 9.94%

The initial biological objective for productivity, intended to support the goal of a population growth rate of two-fold over three generations (which equals a CRR of 1.26), is freshwater average survival of juvenile Chinook salmon of 2.13%. By year 10, the following will be achieved: 1) the minimum juvenile production successfully migrating past Caswell RST relative to water year (WY) type and spawner stock (previous fall escapement) shown in Table 3 will be exceeded; and 2) survival from Caswell to Vernalis will be equal to or greater than 68.41% (pro-rata estimate of the average of upstream survival and through-Delta survival). To achieve the median freshwater survival objective, a proportional increase in through-Delta survival was assumed; this translates to through-Delta survival of 31.32%. Attainment of the companion through-Delta survival rate is not required to satisfy this productivity objective for the Stanislaus River.

Table 3
Production by Year 9 at Caswell Needed to Attain Target Growth Rate Assuming Proportionate Improvement in Pre-Delta and Delta Survival

	Unimpaired Year Type		
	Dry	**Medium**	**Wet**
Egg-CRST Survival	5%	9.94%	15%
Spawning Stock			
2,000	350K	693K	1.04M
4,000	700K	1.39M	2.09M
6,000	1M	2.08M	3.14M
8,000	1.4M	2.77M	4.19M

Notes:
Table assumes 60% female spawners; 5,813 eggs per female; and a survival of 68.74% from Caswell to Vernalis.
CRST = Caswell rotary screw trap

6.2.5.3.2 Objective B: Median Egg to Caswell Survival Equals 13.1%

The SEP group's second phase of productivity improvement, necessary to establish population resilience (defined by the SEP group as a CRR of 2.5), requires average freshwater survival of 4.22%. Note that the CRR associated with productivity sub-objective "a" (CRR=1.26; see above) would lead to a situation where low production in any one year would severely constrain production in the subsequent generation (i.e., the population would not be resilient). A higher CRR is in keeping with Central Valley Goals and Central Valley Objectives for this population. For example, the AFRP specifies maintenance of a 5-year running average for natural production targets and the Plan Goal and this Biological Objective are designed to ensure that survival rates in the river environment do not prevent attainment of abundance targets following years with low returns (i.e., as would be necessary to hit a 5-year running average). Although freshwater survival of 4.22% is higher than current survival estimates, the SEP group considered it to be reasonable and achievable, after 15 years of restoration effort, especially because it is well-below typical freshwater survival for Chinook salmon populations across their range (see below).

By year 15, the following will be achieved: 1) the minimum juvenile production successfully migrating past the Caswell RST relative to WY type and spawner stock (previous fall escapement) shown in Table 4 will be exceeded; and 2) survival from Caswell to Vernalis will be equal to or greater than 73.18% (pro-rata estimate of the average of upstream survival and through-Delta survival). To achieve the median freshwater survival objective, a proportional increase in through-Delta survival was assumed; this translates to through-Delta survival of 44.1%. Attainment of the companion through-Delta survival rate is not required to satisfy the productivity objective for the Stanislaus River.

Table 4
Production by Year 15 at Caswell Needed to Attain Abundance Target Assuming Proportionate Improvement in Pre-Delta and Delta Survival

	Unimpaired Year Type		
	Dry	**Medium**	**Wet**
Egg-CRST Survival	9%	13.1%	18%
Spawning Stock			
2,000	450K	654K	900K
4,000	900K	1.31M	1.8M[1]

6,000	1.35M	1.96M	2.7M[1]
8,000	1.8M	2.62M[1]	3.6M[1]

Notes:
Table assumes 60% female spawners; 5,813 eggs per female; approximately 73.18% Caswell-Vernalis survival.
[1] Assuming survivals below Caswell meet targets described here, juvenile production of approximately 1.97M at Caswell RST would suffice to attain goal.
CRST = Caswell rotary screw trap

6.2.5.3.3 Objective C: Median Egg to Caswell Survival Equals 25.1%

The SEP group adopted the average survival rate reported by Quinn (2005)—10% egg-to-smolt survival—as typical of Chinook salmon populations, both because it was the most recent study and because this value was approximately the mid-point of the values from the two other studies. Although a 10% freshwater survival rate is much higher than current survival rates on the Stanislaus River, the SEP group considered this objective to be attainable and perhaps conservative, after 24 years of restoration effort. This was because: 1) the value is typical of other Chinook salmon populations studied in human managed systems from across the species' range; and 2) freshwater migrations required of Chinook salmon juveniles from the Stanislaus River are among the shortest in the entire Central Valley. By year 24, the following will be achieved: 1) the minimum juvenile production successfully migrating past Caswell RST relative to WY type and spawner stock (previous fall escapement) shown in Table 5 will be exceeded; and 2) survival from Caswell to Vernalis will be equal to or greater than 79.68% (pro-rata estimate of the average of upstream survival and through-Delta survival). Proportional increase to in-River and through-Delta survival rates would have required through-Delta survival that the SEP group judged to be not achievable on a sustained basis (i.e., not S.M.A.R.T.). Maximum median through-Delta survival was assumed to be approximately 50%. Thus, to achieve the target freshwater survival objective, through-Delta survival of 50% was assumed. Attainment of the companion through-Delta survival rate is not required to satisfy this productivity objective for the Stanislaus River.

Table 5
Production by Year 24 at Caswell Needed to Attain Abundance Target Assuming Proportionate Improvement in Pre-Delta and Delta Survival

	Unimpaired Year Type		
	Dry	Medium	Wet
Egg-CRST Survival	15%	25.10%	35%

Spawning Stock			
2,000	750K	1.26M	1.75M
4,000	1.5M	2.51M	3.5M
6,000	2.25M	3.77M	5.25M
8,000	3M	5.02M	7M

Notes:
Table assumes 60% female spawners; 5813 eggs per female; approximately 79.7% Caswell-Vernalis survival.
CRST = Caswell rotary screw trap

6.2.5.4 Rationale for a Timing of Migration Life-history Objective

Differences in juvenile Chinook salmon size-at and timing-of migration are believed to represent different life-history strategies. As discussed in Section 3.2 this "portfolio effect" of spreading risk through life-history diversity is thought to maximize survival across the subsequent environments salmon are exposed to (e.g., mainstem river, Delta, and ocean). The ideal timing of migration for any size-class is unknown and believed to be variable across years (i.e., depending on future conditions in subsequent environments). Migration of Chinook salmon of different sizes across a broad migration window will reveal that the river environment is supporting a wide range of life-history types that are characteristic of healthy Chinook salmon populations. A migration timing window is necessary to ensure that river function is maintained throughout a normal migration period for fall-run Chinook salmon. The SEP group recognized that it would not be desirable to retain fish in the Stanislaus River beyond the time each year where temperatures in the lower San Joaquin River are unsuitable; thus, migration timing windows may be truncated in any year when temperatures exceed a threshold temperature prior to the end of the time period specified.

6.2.5.5 Approach to the Timing of Migration Life-history Objective

The metric for this biological objective is the presence (absence) of fall-run Chinook salmon juveniles measured on a weekly basis. The timing windows reflected here are similar to those already detected by RSTs on the Stanislaus River. For example, in 2000 (a wet year), outmigrants were detected at Caswell from January 2 to June 25. In 2003 (a drier year) outmigrants were detected at Caswell from January 23 to May 8. A summary of outmigrant timing data collected at the Caswell RST from 1996 to 2014 is provided in Table 6.

Table 6
Migration Windows (Days) of Migratory Phenotypes of Juvenile Salmon Collected at Caswell Rotary Screw Trap

Year	Fry (Less than 55mm [2.2 in] Fork Length)	Parr (Greater than 55mm [2.2 in] to less than 75mm [3 in] Fork Length)	Smolt (Greater than 75mm [3 in] Fork Length)
1996	72 (February 1 to April 12)[2]	101 (February 16 to May 26)	145 (February 4 to June 27)
1997*[1]	--	--	--
1998	117 (January 3 to April 29)	98 (February 18 to May 26)	117 (March 6 to June 30)
1999	143 (January 13 to June 4)	120 (February 14 to June 13)	117 (March 6 to June 30)
2000	115 (January 2 to April 25)	116 (February 4 to May 29)	110 (March 8 to June 25)
2001	133 (January 1 to May 13)	96 (March 7 to June 10)	152 (January 17 to June 17)
2002	81 (January 11 to April 1)	123 (February 9 to June 11)	104 (March 1 to June 12)
2003	80 (January 23 to April 12)	118 (February 5 to June 2)	107 (February 24 to June 10)
2004	90 (January 19 to April 17)	96 (February 26 to May 31)	101 (February 29 to June 8)
2005	102 (January 1 to April 12)	118 (February 14 to June 11)	164 (January 9 to June 21)
2006*	--	--	--
2007	127 (January 7 to May 13)	107 (March 10 to June 24)	124 (February 24 to June 27)
2008	72 (January 20 to March 31)	64 (February 29 to May 2)	91 (March 18 to June 16)
2009	85 (January 9 to April 3)	61 (March 8 to May 7)	87 (March 8 to June 2)
2010	122 (January 11 to May 12)	71 (March 3 to May 12)	113 (February 9 to June 1)
2011	130 (January 1 to May 10)	78 (February 14 to May 2)	127 (February 21 to June 27)
2012	121 (January 12 to May 11)	92 (March 12 to June 11)	119 (March 3 to June 29)
2013	109 (January 1 to April 19)	103 (February 22 to June 4)	134 (January 22 to June 4)
2014	128 (January 4 to May 11)	133 (January 21 to June 2)	112 (February 17 to June 8)

Notes:
[1] Years marked by asterisk had trap issues and the data cannot be included.
[2] The range shows the first and last detection.
Source: Cramer Fish Sciences Rotary Screw Trap database in Zeug et al. 2014; Table from Sturrock et al. in review
mm = millimeter
in = inch

For this objective, parr and smolt migration windows were set 1 to 2 weeks earlier than is typically detected currently; this reflects the desire to produce faster growth rates in-river and thus, earlier appearance of larger size classes among outmigrants. The SEP group considered these objectives to be easily attainable, because the minimum required to demonstrate the suitability of the river corridor (for this objective) is the detection of one juvenile fish in a given size category each week.

The SEP group recognizes that distinguishing in the field between fall- and spring-run Chinook salmon juveniles is challenging at this time; thus, the objective will be satisfied by detection of any Chinook salmon juveniles in the specified time window, without regard to parentage. If field techniques that allow distinction between juveniles of different runs become available, the SEP group will consider how the objective should be implemented on a run specific basis.

6.2.5.6 Timing of Migration Life-history Objective

By year 10, in every year, migration of fall-run Chinook salmon will be detected in every week between the dates shown in Table 7, until such time that the mean daily temperature at Mossdale is greater than or equal to 25 degrees Celsius (°C) (77 degrees Fahrenheit [°F]).

Table 7
Fall-Run Chinook Salmon Timing of Migration Objectives

Size Class	Caswell RST		Mossdale[1] Trawl	
	Start Week	**End Week**	**Start Week**	**End Week**
Fry (smaller than 55 mm [2.2 in])	Last of January	Second of April	N/A[2]	N/A[2]
Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in])	First of February	Last of May	Second of February	First of June
Smolt (larger than 75 mm [3 in])	Third of February	First of June	February	June

Notes:
[1] Tributary contribution can be assigned (e.g., by otolith analyses).
[2] Mossdale Trawl does not reliably detect fish smaller than 55 mm (2.2 in).
mm = millimeter
in = inch

6.2.5.7 Rationale for a Size at Migration Life-history Objective

Different juvenile Chinook salmon size-at-migration classes were assumed to be a proxy for different life-history strategies. It is important to have a portfolio of such strategies to improve overall survival rates across years (Beechie et al. 2006; Miller et al. 2010; Satterthwaite et al. 2014). Currently, in wet years, the Stanislaus River produces a very large proportion of fry-sized juvenile migrants. For example, in 2000 85% of total outmigrants at Caswell were fry-sized with a smaller proportion of smolt-sized juveniles (5%). These smaller-sized fish likely have lower outmigration survival rates (Sturrock et al. in review). Conversely, in dry years such as 2003, a larger proportion of outmigrants are smolt-sized, with approximately 34% of total outmigrants at Caswell classified as smolt-sized (Table 8). The SEP group is concerned that smolt-sized fish may not survive a late-spring migration through the lower Stanislaus River and San Joaquin rivers, due to prohibitively warm temperatures during dry years. In addition, it is believed that the distribution of sizes-at-migration is largely a response to reservoir release patterns (Fuller 2013) with large numbers of fry migrating during peak flow periods of wet years. A size-at-migration objective complements productivity objectives by ensuring that large numbers of migrants are not "produced" simply by flushing small fish out of the river to the Estuary, where they could suffer extremely high mortality rates. A more balanced proportional representation of outmigrant size classes across the full winter/spring migration season would allow for bet-hedging, and likely result in increased survival across years.

Table 8
Abundance and Proportions of Fry, Parr, and Smolt Outmigrants Sampled by Rotary Screw Traps, and the Timing of Migration from Stanislaus River in 2000 and 2003

Outmigration Cohort	Migratory Phenotype	N (95% Confidence Interval)	Proportion of the Sample	Duration of Migratory Period (Range)	Duration of "Peak" Migratory Period (Interquartile Range)	Peak Migration Date (Median)
2000 (wetter)	Fry	1,837,656 (1,337,351 to 2,495,523)	0.85	115 days (January 2 to April 25)	4 days (February 14 to February 17)	February 16
	Parr	212,042 (141,238 to 310,174)	0.1	116 days (February 4 to May 29)	29 days (March 18 to April 15)	April 1
	Smolt	100,827 (68,732 to 142,920)	0.05	110 days (March 8 to June 25)	34 days (April 15 to May 18)	May 9
	TOTAL	2,150,524 (1,577,379 to 2,915,064)				
2003 (drier)	Fry	79,862 (59,795 to 103,916)	0.5	80 days (January 23 to April 12)	4 days (January 27 to January 30)	January 29

	Parr	25,729 (17,889 to 36,282)	0.16	118 days (February 5 to June 2)	27 days (March 18 to April 13)	March 21
	Smolt	55,573 (38,362 to 77,486)	0.34	107 days (February 24 to June 10)	21 days (April 18 to May 8)	April 25
	TOTAL	161,164 (120,133 to 210,360)				

Note:
Source: Sturrock et al. (in review)

6.2.5.8 Approach to a Size at Migration Life-history Objective

The SEP group recognized that prescribing specific size-class distributions was not wise or possible because size-class distributions naturally fluctuate (stochastically and with respect to environmental conditions) from year to year and the ideal size-class distribution for conditions in any given year are unknowable, in advance. On the other hand, the SEP group believed that it was possible to identify minimum thresholds for the relative abundance of different size-classes because failure to produce these minimum distributions would indicate a failure of the river environment to support a portfolio of life-history strategies. Objectives were not prescriptive; rather, the SEP group asked the following question, "Below what proportion of a given size-class would we be concerned that the river was not providing adequate opportunities for the life-history strategies associated with that size class?" The biological objectives described here anticipate the attainment of environmental objectives (i.e., chemical, physical, and biological conditions) that would allow for greater in-river rearing opportunities. The ranges represent:

- Fry: Easily attained under current conditions (A. Sturrock, personal communication, unpublished data)
- Parr: The target for wetter years is approximately double the proportion of parr that is currently observed in wetter years (A. Sturrock, personal communication, unpublished data). The target for drier years is approximately 1.5 times the proportion currently observed during drier years. The intent is to set a reasonable target for improved growth and rearing on the tributaries.
- Smolt: The target for wetter years is approximately double the proportion of smolt migrants currently observed in wetter years. The target for drier years is currently

attained; in fact, the SEP group was concerned that the Stanislaus River production is weighted too heavily toward larger smolts that rear in the system longer during drier years, and that outmigrate later and are at risk due to high temperatures in the lower river during drier years.

Again, the SEP group included a temperature off-ramp for measuring the proportional production of each of these size classes to account for the low likelihood of survival for fish entering the lower San Joaquin River when temperatures exceeded a critical threshold.

6.2.5.9 Size at Migration Life-history Objective

By year 12, annual emigrant size-class distribution as measured at Caswell RST (which includes only juveniles that migrate before daily mean temperatures exceed 25°C (77°F) at Mossdale) will be as detailed in Table 9.

Table 9
Fall-Run Chinook Salmon Size at Migratory Objectives

Size Class	Wetter Years	Drier Years
Fry (smaller than 55 mm [2.2 in])	20% min	20% min
Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in])	20% min	30% min
Smolt[1] (larger than 75 mm [3 in])	10% min	20% min

Notes:
Initial estimates of size class distribution are based on Sturrock et al. (in review)
[1] Includes only juveniles that migrate before daily mean temperatures greater than 25°C (77°F) at Mossdale.
mm = millimeter
in = inch

Size distribution of migrants will be measured on an annual basis, but can also serve to guide management within each year (e.g., the 25°C [77°F] temperature threshold can be used as a trigger to stimulate migration earlier during dry years).

6.2.5.10 Rationale for a Genetic Objective

The primary genetic concern for fall-run Chinook salmon in the Stanislaus River are the influence of hatchery produced fish on the fitness of the local stock and introgression with spring-run Chinook salmon. Artificial propagation of salmon in hatcheries has long played a role in meeting harvest and conservation goals for salmon and steelhead in California. The life-history diversity and productivity objectives described above will only be achieved if managers can ensure little or no deleterious consequences to natural populations from hatchery-origin fish. It is necessary to achieve a low level of extinction risk for fall-run Chinook salmon, and part of attaining that acceptable level of risk relates to implementing hatchery best management practices.

Current escapement to the Stanislaus River reflects a very high proportion of hatchery fish produced in other river systems. In 2007, CDFW began marking and tagging a constant fraction (25%) of hatchery production (Constant Fractional Marking Program). Escapement years 2010 and 2011 were the first 2 years where juveniles from this marking effort returned as age 2-, 3-, and 4-year-olds to spawn in freshwater habitats as adults. Approximately 50% and 83% of the adults that returned in 2010 and 2011, respectively, were strays from hatcheries and were not produced from parents who spawned successfully in the Stanislaus River (Figure 6; Kormos et al. 2012; Palmer-Zwalen and Kormos 2013). The majority of the strays were fish that were trucked and released into net-pens in the Estuary (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013). Releases of juveniles in-river versus out-of-basin have been found to have a significant effect on the likelihood adults are to stray to non-natal rivers (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013).

The rationale for establishing a fall-run Chinook salmon biological objective related to minimizing introgression with spring-run Chinook salmon mirrors the approach described below in the spring-run Chinook salmon biological objectives section.

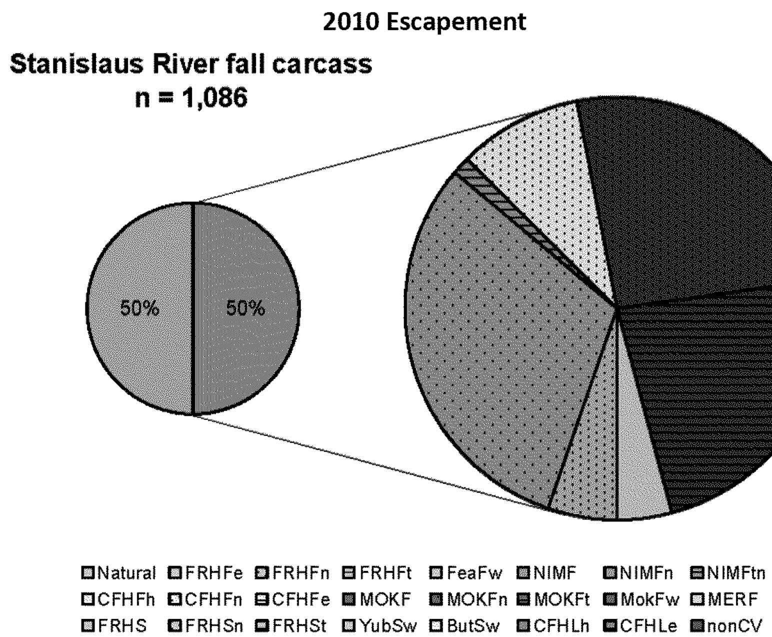
6.2.5.11 Approach to a Genetic Objective

6.2.5.11.1 Hatchery Influence

The science of hatcheries focuses on several key management concepts that, if implemented, would make a greater contribution to harvest than the existing natural habitat can sustain on its own (HSRG 2014). For integrated hatcheries, one key element is managing hatchery- and natural-origin fish as two components of a single gene pool that is locally adapted to the natural habitat. The SEP group relied on existing literature and reports regarding targets for minimizing hatchery influence in the Central Valley in order to identify objectives for the maximum level of hatchery-influence on the Stanislaus River. The SEP group acknowledged that hatchery impacts are a regional concern and must be managed throughout the San Joaquin River basin and beyond. Still, an important component of minimizing hatchery influence relates to conditions on the target stream and the health of its natural spawning populations.

6.2.5.11.2 Introgression

The approach for establishing a fall-run Chinook salmon biological objective related to minimizing introgression with spring-run Chinook salmon mirrors the approach described subsequently in the spring-run Chinook salmon biological objectives section.



2011 Escapement

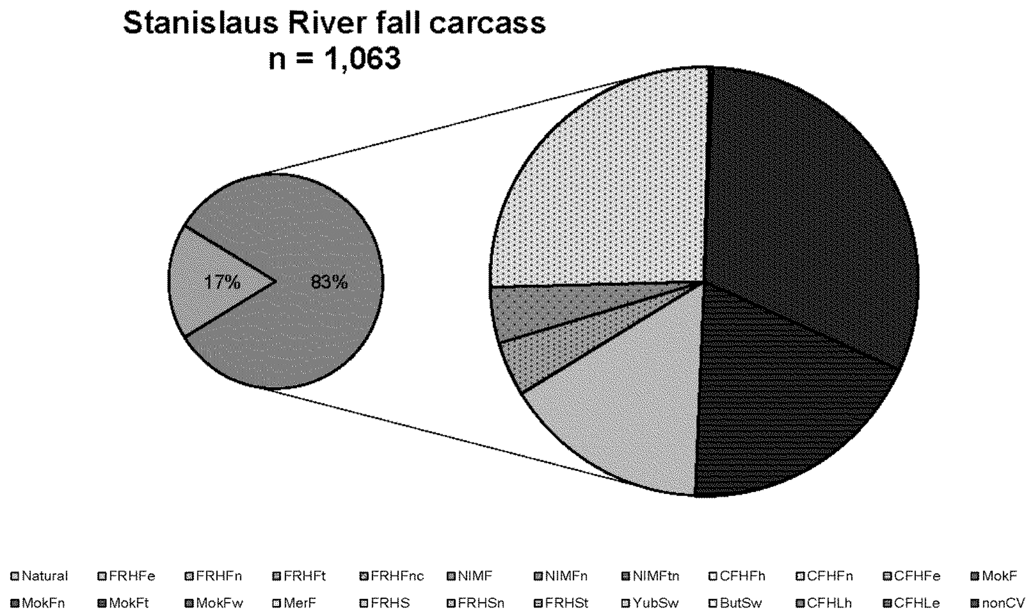


Figure 6

Estimates of Natural- and Hatchery-Produced Fish Contributions to Stanislaus River Spawning Population

Sources: Kormos et al. 2012; Palmer-Zwahlen and Kormos 2013

6.2.5.12 Genetic Objective

6.2.5.12.1 Hatchery Influence

Benchmark metrics have been established based on genetic models to reduce the pHOS to less than 20% of adult spawners. Therefore, the genetic objective for fall-run Chinook salmon is that by year XX achieve a spawning population that consists of greater than 80% Stanislaus River produced fish.

6.2.5.12.2 Introgression

Establish conditions in the Stanislaus River that support fall-run Chinook salmon spawning success and reinforcement of long-term genetic integrity as measured by greater than 98% of fall-run Chinook salmon spawning with other fall run Chinook salmon.

6.3 Spring-run Chinook Salmon

6.3.1 What is the Problem?

Spring-run Chinook salmon populations throughout the Central Valley are extremely constrained with regard to all viability criteria (Yoshiyama et al. 2001; Lindley et al. 2007; NMFS 2014). These problems are most evident in the San Joaquin River basin, where spring-run Chinook salmon were extirpated following the construction of impassable dams in the middle of the 20th Century. The spring-run was historically the most abundant run of Chinook salmon in the San Joaquin River basin and was among the largest runs along the Pacific Coast (Fry 1961; CDFG 1972, 1990; Yoshiyama et al. 2001). Prior to major dam construction in the middle of the 20th century, spring-run were the dominant Chinook salmon populations on the Stanislaus River (CDFG 1972). Until recently, spring-run Chinook salmon were considered to be extirpated from all waterways in the San Joaquin River basin. There have been manual spring-run Chinook salmon reintroduction efforts on the San Joaquin mainstem below Friant Dam as part of the San Joaquin River Restoration Program. There is growing recognition that spring-running Chinook salmon adults have been observed in San Joaquin tributaries in recent years (Franks 2012); however, the source of these fish is unknown.

Throughout the Central Valley, genetic threats to spring-run Chinook include introgression with fall-run Chinook salmon (CDFG 1998; Banks et al. 2000), wherever these two populations are forced to spawn in the same habitat (i.e., because dams block passage into the higher elevation habitats historically utilized by spring-run). Genetic introgression with fall run Chinook salmon is a threat to the unique morphological, behavioral, and life historical phenotypes and genotypic distributions that make spring run distinctive (Smith et al. 1995; CDFG 1998; Banks et al. 2000). Thus, maintaining opportunities for temporal and spatial isolation of spawning between fall- and spring-run Chinook salmon is a challenge that efforts to restore spring-run Chinook salmon to the San Joaquin River basin need to address.

6.3.2 What Outcome(s) (Central Valley Goals) Will Solve the Problem?

Abundance. Goals for abundance of Central Valley spring-run Chinook salmon are documented in Hanson (2007, 2008), NMFS (2014), and in USFWS (2001). These plans stem from different laws (or legal settlements) and take different approaches to restoration; for example, they cover different geographies within the Central Valley and seek to attain conceptually different standards for population restoration. As a result, there are multiple restoration goals for abundance of spring-run Chinook salmon in the Central Valley and San Joaquin River basin, but no single goal applies across the Central Valley, except for the narrative goal described in CDFG Code § 5937, which states that dam operators must maintain fish populations "in good condition." This requirement has not been specifically defined for individual rivers. Thus, the SEP group worked from the clear intent of existing policies to restore spring-run Chinook salmon in rivers throughout the Central Valley that they historically occupied, and identified goals and defined objectives that would satisfy that intent in the San Joaquin River basin, from a biological perspective.

Productivity and Life-history Diversity. Improvements in spring-run Chinook salmon productivity (measured as juvenile survival and adult migration and holding success in freshwater) and increased life-history diversity (i.e., size at and timing of juvenile migration) are clearly necessary to: 1) achieve abundance targets for spring-run Chinook salmon in the Central Valley; 2) maintain fish "in good condition" (CDFG Code § 5937); 3) attain acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (McElhany et al. 2000); and 4) to be consistent with other fisheries-related and water management related policies. No specific goal statements for these attributes have been defined, so the SEP group worked to define Plan Goals for spring-run Chinook salmon that were appropriate to the geographic and policy scope of this effort.

Spatial Diversity. The NMFS (2014) Recovery Plan for Central Valley salmonids specifies that spring-run Chinook salmon populations will be restored to the southern Sierra diversity group (i.e., the San Joaquin River basin) such that "two populations [are] at low risk of extinction" and "multiple populations at [are maintained at no worse than] a moderate risk of extinction." Restoration of spring-run abundance, productivity, and life-history diversity to the San Joaquin River tributaries and mainstem will serve to improve the spatial distribution of this distinct run throughout the Central Valley.

Genetic Diversity. Eliminating genetic introgression with fall-run or reducing it to a very low level is a major goal for the maintenance and restoration of spring-run Chinook salmon in the Central Valley (Lindley et al. 2007; HSRG 2014). Thus, providing opportunities for spring-run reproductive isolation is particularly important for the maintenance of spring-run populations in rivers where high elevation habitat is blocked by dams.

6.3.3 What Does Solving the Problem Look Like (Central Valley Objectives)?

Abundance. As with other anadromous populations in the SEP's scope, the SEP group used abundance targets as Central Valley objectives, but not as Plan Goals or biological objectives specific to the Stanislaus River. The SEP group recognized that attainment of a Central Valley abundance objective for any particular river requires adequate conditions throughout the fish's life cycle; abiotic and biotic conditions in the Stanislaus River and lower San Joaquin rivers must support, but may not be entirely sufficient, to result in attainment of this objective, depending on conditions in the Delta and ocean. Thus, abundance, per se, is not a Plan Goals and no specific abundance target was established as a biological objective for spring-run on the Stanislaus River. An understanding of desired conditions for abundance of spring-run Chinook salmon is still necessary to set a context for determining environmental objectives (e.g., physical, chemical, and biological conditions necessary to support juvenile rearing; see below) for the Stanislaus River that will be necessary to support spring-run salmon restoration in the Central Valley.

The AFRP does not identify production targets for spring-run Chinook salmon from San Joaquin River tributaries, as it does for fall-run (USFWS 2001). This is likely because spring run Chinook salmon were not detected in the San Joaquin River basin when the CVPIA was passed in 1992 or when the AFRP was finalized in 2001. The NMFS Recovery Plan (NMFS 2014) identifies, from an ESA-perspective, what level of spring-run Chinook salmon abundance is sufficient to achieve the narrow goal of de-listing this population. The Central Valley goal particular to the San Joaquin River basin states that there must be at least two populations at low risk of extinction in the southern Sierra diversity group. For a population to have a "low risk" of extinction, NMFS (2014) specifies, among other things, that it must achieve a census population size of at least 2,500 individuals. Spread over a 3-year generation length, this translates to a 3-year running average population of approximately 833 returning adults.

The SEP group determined that de-listing spring-run Chinook salmon, as per the NMFS Recovery Plan, would represent only a preliminary step to fully restoring spring-run Chinook salmon to the San Joaquin River basin and Stanislaus River. In other words, the SEP group's view was that delisting was a preliminary, not a final goal, for this salmon population. The SEP group acknowledged that, historically, the Stanislaus River's spring-run

Chinook salmon population was larger than its fall-run population (CDFG 1972; Yoshiyama et al. 2001) and found no biological reason to expect that the spring-run population would be only a small fraction of the fall-run Chinook salmon population in the future, following restoration of the river. A Stanislaus River population of 833 returning spring-run spawners per year would be less than 10% of the escapement of approximately 13,225 fish that is implied by the Central Valley objective for Stanislaus River fall-run Chinook salmon (assuming current harvest rates, see Table 2). Also, the SEP group found no reason why the Stanislaus River would not be capable of supporting as many spring-run or total Chinook salmon as the restored San Joaquin mainstem below Friant Dam. The San Joaquin River Restoration Program has a target of restoring 30,000 spring-run Chinook salmon and 10,000 fall-run Chinook salmon to the mainstem below Friant Dam (Hanson 2007, 2008). Finally, for comparison, Butte Creek, a tributary to the Sacramento River that is much smaller than the Stanislaus River, has received escapement greater than 10,000 spring-run Chinook salmon in more than half the years since carcass surveys began in in 2001 (GrandTab 2014). As a result of these considerations, the SEP group determined that the Central Valley objective for the production of Stanislaus River spring-run Chinook salmon roughly equals the Central Valley objective for fall-run Chinook salmon production, which is the natural production in the ocean of 22,000 2-year old salmon per year on average. The SEP group believed this Central Valley objective for the Stanislaus River may actually be conservative.

Spatial Distribution. As discussed above, the NMFS (2014) calls for multiple populations in the San Joaquin River basin to be established, at least two of which must be at “low risk” of extinction and others that must be at no greater than “moderate risk” of extinction.

Productivity. The SEP group determined that Central Valley objectives for productivity of young-of-the-year spring-run Chinook salmon are identical to those for fall-run Chinook salmon. The AFRP (USFWS 2001) and CVPIA provide guidance regarding the desired rate of population growth for anadromous fish populations in the Central Valley as a whole. Even without specific guidance from CVPIA regarding the number of spring-run Chinook salmon that should be restored to the San Joaquin River basin, the Act is clear that anadromous fish populations in the Central Valley were expected double from a baseline within 10 years. Furthermore, the CVPIA and AFRP targets are expressed as 5-year averages, implying that populations would be resilient such that periodic years of low production (due to any cause) do not constrain a population's ability to re-attain any abundance targets in the following generation. In addition, restoration of a spring-run Chinook salmon population to a state where it is "in good condition" (per CDFG Code § 5937) was taken to mean that, spring-run Chinook salmon below dams in the Central Valley should display survival rates that support population growth rates typical of this species throughout its range. The SEP group also looked to other viable populations of Chinook salmon to gauge freshwater survival rates that would characterize a restored Chinook salmon population on the Stanislaus River.

Spring-run Chinook salmon are different from fall-run Chinook salmon in that they return to freshwater several months before they spawn. They wait in freshwater, without feeding, throughout the summer in a process known as "holding". This protracted period of freshwater residence exposes spring-run Chinook salmon adults to additional mortality in freshwater if environmental conditions are not adequate. Maintenance of the unique life-history strategy of spring-run Chinook salmon requires protection of all phases of their life cycle, especially the holding period. No Central Valley-wide objectives have been identified for survival through and spawning success post-holding.

Life-history Diversity. Spring-run Chinook salmon are noted for producing a yearling life-history variant. Yearling juveniles spend up to a full year in rivers before migrating to the ocean (Moyle 2002; Williams 2006). No policies speak directly to Central Valley-wide objectives for necessary improvements in the life-history diversity of spring-run Chinook salmon. However, there is increasing evidence that life-history strategies of spring run Chinook salmon are constrained and improvements will be necessary to attain Central Valley goals for this population. Further, there is evidence of juvenile salmon that are likely not sub-yearling progeny of fall-run Chinook salmon and may represent the yearling life-history strategy (Figure 7). From 1996 to 2013 at total of 49 yearlings (visually defined) were detected prior to May 1st at the Caswell RST (Zeug et al. 2014; Cramer Fish Sciences unpublished data).

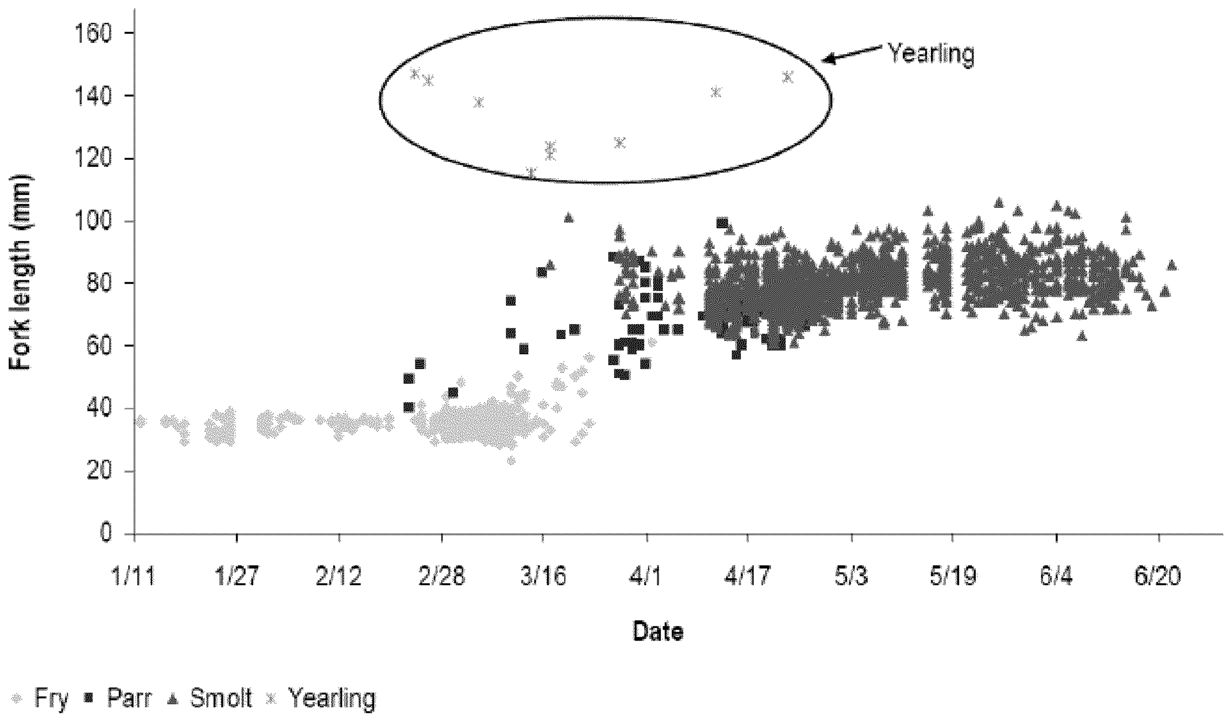


Figure 7
Estimates of Natural- and Hatchery-produced Fish Contributions to Stanislaus River Spawning Population

Source: Watry et al. 2007.

Genetic Diversity. Specific gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations in the Central Valley (Lindley et al. 2007; HSRG 2014).

6.3.4 How Much Will this Effort Contribute to Attainment of these Central Valley Objectives (Plan Goals)?

As described, the scope of the SEP group's current effort is the Stanislaus River through the lower San Joaquin River to the Delta. Specific goals and objectives for the Stanislaus and lower San Joaquin rivers were developed to support the system-wide goals identified.

Abundance. As described above, no abundance targets, per se, were set as Plan Goals for the Stanislaus River population of fall-run Chinook salmon. However, in order to appropriately scale environmental objectives for the this river, it was assumed that spring run Chinook salmon production from the Stanislaus River would be roughly equivalent to the Central Valley objective for fall-run Chinook salmon (or 22,000 fish per year on average). The adult returns (escapement) that would result from this level of ocean production of spring-run depends on assumptions regarding ocean and in-river harvest targets; such targets are zero currently, because the spring-run Chinook salmon is endangered. However, fisheries may be restored as spring-run populations are restored across the Central Valley.

Spatial Distribution. The Stanislaus River watershed is believed to be amongst the most likely candidates in the southern Sierra diversity group to support a population of spring-run Chinook salmon at low risk of extinction, give the current habitat available below dams. As a result of the geographic limits set by this scope, specific Plan Goals and objectives were not required for the spatial distribution of spring-run Chinook salmon; the SEP group's focus on restoring spring-run abundance, life-history diversity, productivity, and genetic integrity to the Stanislaus River satisfies, in part, the spatial distribution objectives implied by the Central Valley goals for spatial distribution.

Productivity. Central Valley goals and objectives were used to guide development of Plan Goals for productivity (freshwater survival rates). The goals for spring-run Chinook salmon productivity track those for fall-run Chinook salmon. The goals are to be implemented in phases and become progressively more protective over time, to achieve freshwater survival rates sufficient to generate:

1. Population growth rates consistent with the Central Valley goal of increasing the population two-fold in three generations.
2. Population resilience, represented by freshwater survival rates needed to re attain production targets, following periods of low production, within one generation.
3. Freshwater survival rates that are typical of other self-sustaining populations of ocean-type Chinook salmon.

The SEP group acknowledges that it would be extremely difficult or impossible to achieve freshwater survival targets without improvement in both the river and Delta environments; thus necessary improvements in overall freshwater survival were distributed across riverine and estuarine habitats.

Life-history Diversity. Life-history diversity must be maintained to allow for Chinook salmon populations to respond to varying climatic, hydrologic, and ocean conditions over time (Beechie et al. 2006; Miller et al 2010; Satterthwaite et al. 2014; Spence and Hall 2010). The Plan goal for spring-run Chinook salmon life-history diversity was to support the fullest expression of spring-run Chinook salmon life-history diversity, as seen in other Central Valley populations and in other rivers that support this phenotype. In particular, a goal for spring-run population restoration on the Stanislaus River is to achieve measureable production of yearling juveniles, a life-history type that is the hallmark of stream-type Chinook salmon such as the spring-run.

To estimate the timeframe (the "T" in S.M.A.R.T. objectives) for when the spring-run Chinook salmon life-history diversity objectives would be expected to be met, both the potential for a spring-run Chinook salmon population to re-colonize or expand in the Stanislaus River and the essential needs for restoring salmon diversity were considered (McElhany et al. 2000).

There is potential for a spring-run Chinook salmon population to re-colonize and persist in the Stanislaus River if the necessary physical and chemical conditions are provided. This assumption is based on the facts that the Stanislaus River historically supported an independent spring-run Chinook salmon population (Yoshiyama et al. 2001; Lindley et al. 2004), spring-running Chinook salmon have recently been observed in the Stanislaus River (NMFS 2013a), and the San Joaquin River Restoration Program is in the process of reintroducing spring-run Chinook salmon to the San Joaquin River (http://www.restoresjr.net/), some of which will stray into the Stanislaus River. Salmon straying is a natural biological process that results in the establishment or re-establishment of populations (Pess et al. 2009, 2014). On average, under natural conditions, 8% of salmon stray from their natal river to spawn in another one.

Given that changes in the physical and chemical conditions in the Stanislaus River lead to the putative extirpation of spring-run Chinook salmon, it is clear that environmental improvements are needed to restore spring-run Chinook salmon. In order to restore the adaptive diversity of Stanislaus River spring-run Chinook salmon, it is essential to: 1) conserve and/or restore the environment to which they adapted; 2) allow natural processes of regeneration and disturbance to occur; and 3) limit or remove human caused selection or straying that weakens the adaptive fit between the population and its environment or limits the population's ability to respond to natural selection (McElhany et al. 2000).

As described in Section 7, environmental objectives developed by the SEP group are intended to represent environmental conditions needed to support and further expand Chinook salmon and steelhead populations within the San Joaquin River basin. The environmental objectives will likely need to be achieved before a spring-run Chinook salmon population can re-emerge to express its full life-history diversity. Thus, it is not expected that the life-history diversity objectives for this population will be achieved until the environmental objectives are achieved. Furthermore, the other biological objectives may also need to be achieved before the life-history diversity objectives can be achieved.

Because the life-history diversity objectives are specific to the temporal and size distribution of juvenile outmigration, the environmental objectives for the juvenile rearing and migration life stage likely have the most influence on the life-history diversity objectives. However, all of the environmental and biological objectives will play a role in detecting whether or not the life-history diversity objectives are achieved. Given sampling efficiency limitations, particularly when sampling for relatively elusive yearlings as compared to fry which are less apt to avoid sampling, the attainment of the life-history diversity objectives will be able to be detected more so with a large population than with one that is relatively small. Poor survival at any life stage could decrease the overall number of juveniles produced and limit attainment or detection of the life-history diversity objectives.

Once all of the environmental objectives and the biological objectives for the other life stages are met, it is expected that the population will grow and the conditions for trait diversity will emerge (McElhany et al. 2000). It is then assumed that an additional 9 years (three generations) will be sufficient for the population's abundance, productivity, and diversity to improve such that the attainment of the life-history diversity objectives would be able to be detected. The assumption of 9 years is based on Pess et al. (2014), which reported that most salmon colonizations reached self-sustaining levels in 10 to 20 years. For the purposes of identifying the timeframe when the life-history objectives would be expected to be achieved, after the environmental and other biological objectives have been achieved, a time period less than what would be needed to establish a self-sustaining population seems justified; as such, 9 years is assumed to link the timeframe to the mean generation time of Chinook salmon (i.e., 3 years) (Lindley et al. 2007).

Genetic Diversity. Another Plan Goal is to promote recolonization of the San Joaquin River and its tributaries and the long-term success of individuals that exhibit spring-run life-history characteristics, independent of their near-term genetic origin. The SEP group's intent is to create conditions that support restoration of a self-sustaining spring-run phenotype that contributes to the overall diversity, productivity, abundance, and resilience of Chinook salmon populations in the San Joaquin River basin and the Central Valley as a whole. Establishing and maintaining such a distinct population requires that gene-flow between distinct life-history types be limited. It also requires that environmental objectives support the spring-running phenotype at all life-history stages.

6.3.5 What Suite of Species-specific Outcomes (Biological Objectives) Characterize Success?

In many cases, biological objectives for spring-run Chinook salmon on the Stanislaus River are identical to those the SEP group adopted for fall-run Chinook salmon on this River. This makes sense because, for large portions of their life cycle, spring-run and fall-run Chinook salmon from the same river are exposed to similar or identical conditions. Therefore, juvenile survival and somatic growth rates, young-of-the-year size distribution, and timing of juvenile migration are expected to overlap to a great extent (Yoshiyama et al. 1998; Moyle 2002; Williams 2006). Furthermore, it is not currently possible to distinguish definitively between juvenile fall-run and spring-run Chinook salmon in the field; thus monitoring for differences between these populations' vital rates would be impractical if not impossible.

Substantial and important differences between spring-run and fall-run Chinook salmon are apparent in their upstream migration timing (hence their different names), the protracted delay between migration and spawning ("holding") that spring-run display, and the production of a small but measurable fraction of yearling migrants by spring-run Chinook adults (Figure 8). These differences in behavior and life-history lead to important differences in the environmental conditions that are needed to support spring-run and fall-run Chinook salmon. The sections below focus on biological objectives that are unique to spring run

Chinook salmon.

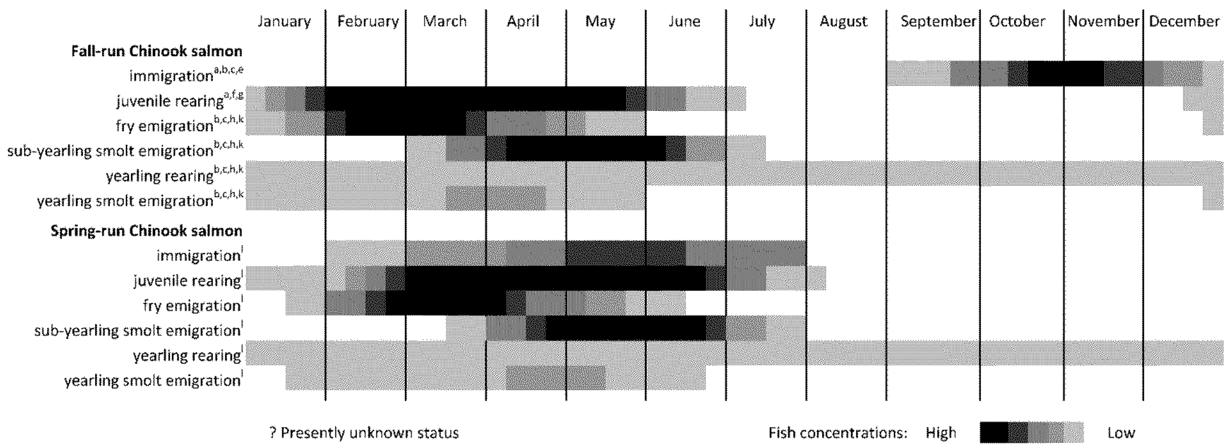


Figure 8

Timeline for Chinook Salmon Migration and Rearing Periods in the San Joaquin River Basin

Note:
Timeline for lower Mokelumne River Chinook salmon and steelhead. Data accrued: 1996 to 2003.

Sources:

a	Moyle 2002
b	Workman 2001
c	Workman 2003
d	Workman 2005
e	Yoshiyama et al. 1998
f	Williams 2006
g	Merz and Setka 2006
h	Watry et al. 2009
I	Merz and Saldate 2007
j	Snider and Titus 1996
k	Seesholtz et al. 2004
l	Fish management work group

6.3.5.1 Rationale for Productivity Objectives

The Plan Goals for productivity (survival) of juvenile spring-run Chinook salmon are the same as those set for fall-run Chinook salmon. The SEP group found no reason to expect different juvenile survival rates among young-of-year spring-run Chinook salmon juveniles than those it identified for fall-run Chinook salmon in the Stanislaus River. Attainment of environmental objectives (i.e., physical, chemical, and biological conditions) necessary for attainment of fall-run Chinook salmon objectives will, presumably, have the same effect on survival of spring-run Chinook salmon juveniles. This conclusion rests on several assumptions, including that:

1. The objectives for spring-run Chinook salmon adult holding and spawning success are met. If those specific objectives are not attained, the number of juveniles per spawner would be less than expected relative to fall-run Chinook salmon.
2. The production of the yearling life-history phenotype does not far exceed the objectives. Production of yearlings represents an investment in a non-young-of-year migrant strategy. Successful investment (represented by a high proportion of yearling migrants) is a generally desirable outcome. Therefore, the SEP group placed no limit on the maximum proportion of yearling outmigrants.
3. Spring-run ocean mortality will ultimately be similar to current fall-run ocean mortality. Juvenile freshwater survival rates necessary to attain population growth rates or population resilience for spring-run are slightly less than those necessary to achieve the same goals for fall-run Chinook salmon.

The SEP group determined that the objectives for juvenile survival and the number of juveniles per spawner should be the same for fall-run and spring-run Chinook salmon on the Stanislaus River. Should juvenile survival objectives not be met, monitoring for the attainment of adult productivity objectives specific to spring-run Chinook salmon will allow for isolation of the phase of the life-cycle when problems occur (e.g., pre-spawning or post-spawning mortality). This addresses assumption 1, above.

Assumption 2 is explicitly addressed within the objectives for yearling production as that objective includes a specific conversion between yearlings and young-of-year migrants such that overall egg-to-outmigrant survival can be evaluated fairly.

Assumption 3 cannot be addressed at this stage because it is not known how fishing regulations will change to reflect restoration of spring-run Chinook salmon, and there is some amount of spring-run Chinook salmon bycatch in the current fishery. Finally, it is simply impractical at this time to measure differences in the survival rate of spring-run Chinook salmon as compared to co-migrating fall-run Chinook salmon juveniles.

The biological objectives for spring-run Chinook salmon also include targets for adult survival and reproductive rates. Unlike fall-run Chinook salmon, spring-run Chinook salmon experience a prolonged period of holding between their arrival in the river and the onset of spawning. During this holding period, spring-run Chinook salmon may experience conditions that reduce survival or viability of their gametes (Healey 1991; Moyle 2002; Quinn 2005; Williams 2006). Survival and success rates of Chinook salmon during holding periods can strongly influence overall population productivity because, having survived through so many other phases of the life cycle, holding fish are extremely valuable from a population dynamics point of view. The SEP group designed objectives for adult holding success and redd viability that apply specifically to spring-run Chinook salmon. These objectives support the overall goals of restoring the unique behavioral phenotype of spring-run Chinook salmon and establishing acceptable productivity (population growth rates) for this population.

6.3.5.2 Approach to Productivity Objectives

Juvenile Productivity. Specific calculations and assumptions regarding the objectives for juvenile productivity and survival of spring-run Chinook salmon are described in the relevant sections for the fall-run Chinook salmon productivity objectives. Because the survival objectives for spring-run and fall-run juvenile Chinook salmon are the same, the total number of Chinook salmon spawners (fall + spring) results in a total (minimum) number of juvenile Chinook salmon outmigrants (fall + spring) at Caswell and Mossdale; this total does not vary based on the ratio of spring-run to fall-run Chinook salmon spawners.

The total not varying is assumed to occur except in certain circumstance. In addition to the young-of-year size classes identified for fall-run Chinook salmon, the SEP group expects that the existence of spring-run Chinook salmon spawning adults will correspond to production and detection of yearling outmigrants (Moyle 2002; Williams 2006). If yearling production rates or the ratio of spring-run to fall-run Chinook salmon adults is low, the total number of juveniles produced by returning spring-run and fall-run Chinook salmon spawners should not be affected by this “investment” in the yearling life-history strategy; yearlings will be a very small fraction of the total outmigrants resulting from any year-class of eggs. However, investment in yearlings may affect the total number of juveniles expected if the following conditions are met:

- Yearling production is higher than that specified in the life-history size-class distribution objective (above) (suggesting a substantial fraction of spring-run egg production is directed toward a yearling strategy and not a young-of-year [YOY] strategy)

- Spring-run populations are a substantial fraction (greater than 33%) of the total spawning population, such that spring-run Chinook salmon investment in a yearling life-history strategy affects overall productivity estimates

Under these conditions, the productivity objectives, would "credit" the previous year's production of YOY juveniles as though 3 smolts had been produced in year "y" for each yearling-sized fish produced in year y+1. This is based on expectations that ratio of survival of smolt-sized spring-run Chinook salmon to yearling-sized fish would be approximately 33% (i.e., 1 yearling survives for every 3 smolt–sized fish that attempt a yearling strategy). The basis for that conversion is that a 50% overwintering mortality is commonly assumed for fall-run Chinook salmon fingerlings (Mullan 1990; Table 3). Because spring-run Chinook salmon YOY juveniles would need to survive through summer months before emigrating as the following year's yearlings, the SEP group assumed that additional mortality would occur, and therefore increased the expected mortality of spring-run Chinook salmon YOY to the yearling life stage to 66%.

Adult Productivity. The consensus of the SEP group was that the vast majority (greater than 90%) of adult spring-run Chinook salmon that migrate into the Stanislaus River would survive until spawning commences, provided that they were not poached and that they experienced environmental conditions conducive to the survival and production of viable gametes. Generally speaking, there is no reason to expect much mortality of adult Chinook salmon migrants in the river if there is suitable habitat (i.e., cover, temperature, DO) in which they can hold; this life-history strategy would not likely have evolved had mortality been high during the holding period historically. Factors that would lead to the failure of spring-run Chinook salmon spawning success are limited. Adult Chinook salmon do not eat in the river environment and are too big to be eaten themselves by most organisms in the river or riparian environment. This is especially true since historic predators of holding Chinook salmon (e.g., California brown bear, Ursus arctos) have been extirpated for almost a century. Human poaching of over-summering Chinook salmon is suspected to be a problem in some watersheds (Williams 2006), but again, there is no known acceptable limit for illegal harvest.

A very high proportion of redds constructed by fish that over-summered in the river should experience good conditions throughout the incubation period. Good conditions mean that redds will not be dug up by other Chinook salmon, dewatered, scoured, or otherwise heavily disturbed, and will experience water quality conditions that are generally conducive to egg development and fry emergence. Attaining this objective will require sufficient spawning habitat for spring-run that can be isolated (temporally, physically, or by temperature or flow conditions) from spawning fall-run Chinook salmon.

A minimum average egg emergence rate for spring-run spawned in the Stanislaus River was defined as 35%. This expectation is approximately the same as the average (38%) reported by Quinn (2005) and the midpoint of a range (34%) reported by Healey (1991). Levels of successful incubation below this target would indicate significant failure to attain environmental objectives in the river. The SEP group expects that restoration of improved spawning and incubation conditions on the Stanislaus River will lead to egg emergence rates much higher than 35%; current levels of incubation success on Central Valley rivers are indicative of poor conditions throughout the Central Valley (e.g., as compared to CITE). Thus, the 35% emergence value represents only a short-term threshold for incubation success for spring-run; failure to attain this low level of egg emergence would indicate that incubation stressors on spring-run were an immediate impediement to attainment of productivity goals and objectives for this population on the Stanislaus River.

6.3.5.3 Productivity Objectives

6.3.5.3.1 Juvenile

- Objective 1a: Median Egg to Caswell Survival Greater than 9.94%.
- Objective 1b: Median Egg to Caswell Survival Greater than 13.1%.
- Objective 1c: Median Egg to Caswell Survival Equal to 25.1%.

See fall-run Chinook salmon productivity objectives (Section 6.2.5.3) for further description.

6.3.5.3.2 Adult

- Objective 2a: Survival of spring-running migrants that pass the weir through to spawning is at least 90%.

- Objective 2b: Egg viability/deposition such that less than 10% of female carcasses have 10% or more of eggs.
- Objective 2c: Spring-run Chinook salmon redd viability rate of greater than 90% (as projected by monitoring of temperature, flow, and superimposition).
- Objective 2d: Egg-emergence survival rate of at least 35% (measured by surrogates).

6.3.5.4 Rationale for a Timing of Migration Life-history Objective

The Plan Goal is to support the fullest expression of spring-run Chinook salmon life-history diversity in order to increase population stability, resilience, and productivity. Size-at-date of migration was used as a proxy for life-history strategy. An objective that specifies a window for juvenile migration is necessary to ensure that river function is maintained during a normal migration period. Allowing for spring-run Chinook salmon migration throughout a broad migration window is intended to expose some spring-run Chinook salmon juveniles to "optimal" migration conditions (throughout their life cycle) whenever those optimal conditions occur (a timing that is expected to vary unpredictably with the timing of hydrological, estuarine, and marine conditions, across years).

6.3.5.5 Approach to the Timing of Migration Life-history Objective

In other Central Valley watersheds where they co-occur, spring-run Chinook salmon spawning begins approximately 1 month (or more) earlier than fall-run Chinook salmon (Yoshiyama et al. 1998; Moyle 2002); thus, the expectation that detection of migrating fry-sized spring-run Chinook salmon juveniles would begin at least 3 weeks earlier than fall run fry ought to be easily attained in a healthy river.

The migration timeframe for yearling-sized fish was based on yearling emigration data from Mill, Deer, and Butte creeks (Figure 25 of Lindley et al. 2004). The SEP group investigated yearling migration timing pattern in Sacramento River tributaries and determined that among watersheds and across years, yearling emigration occurred throughout the migration period which was weeks or months long, and not in single, short-duration pulses (Ward et al. 2003, 2004; Lindley et al. 2004; McReynolds et al. 2006, 2007; Garmin and McReynolds 2008, 2009). In other words, yearling migration does not appear to occur in a temporally concentrated manner associated with flow fluctuations, as might be expected for fry.

The SEP group recognizes that distinguishing between fall- and spring-run Chinook salmon juveniles in the field is challenging at this time; thus, these life-history objectives will be satisfied by detection of appropriately-sized Chinook salmon juveniles, without regard to parentage, in the specified time window. If field techniques that allow distinction between juveniles of different runs become available, the SEP group will consider how the objective should be implemented on a run-specific basis.

6.3.5.6 Timing of Migration Life-history Objective

By year XX, Chinook salmon monitoring will detect, in every year, migration of spring-run Chinook salmon juveniles as shown in Table 10.

Table 10
Spring-run Chinook Salmon Timing of Migration Objectives

Size/Life-history Type	Frequency	Start	Fall-run Start	End (Both Runs)
Yearling (to be measured 2 calendar years following parent cohort return [escapement])	Detection in at least 50% of weeks between the second week of October to January and 50% of weeks February to April (The division between time periods is intentional and meant to ensure that some yearlings migrate in each of the time periods)	October	—	April
Young of the Year	Every week	First week of January	Last week of January	Second week of April

This yearling migration timing objective will be in place any time spring-run Chinook salmon are spawning on the Stanislaus River. Because overall yearling abundance may be low, the SEP group's expectation is only that yearling-sized Chinook salmon will be detected, at least once, in 50% of weeks between the second week of October and January and in 50% of weeks between February and April. However, it may only be a measureable objective when spring-run escapement and spawning are sufficient to produce a number of yearlings that can satisfy the objective. There are 30 weeks in the entire period, so at least 15 yearlings would need to be detected to meet the objective of at least one yearling detection in 50% of weeks in the two time periods.

The minimum number of yearlings needed to meet the objective implies that a total escapement of at least 16,700 spring-run Chinook salmon is needed. This is based on the assumptions that at least 1.5 yearlings are produced per 1,000 returning adult females (1.5 yearlings per 1,000 female spawners, see size-at-migration objective below), 60% of the escaped fish are females, (as per current estimate for fall-run Chinook salmon, see SEP group calculations for fall-run productivity objective), and a sampling efficiency for yearlings similar to that of Butte Creek, the system from which the minimum yearling/spawner expectation is derived. If the assumptions above are met and escapement is lower than this target, the yearling production objective can be revised to an expectation that roughly equal numbers of yearling are detected in each of the two time periods (October to January and February to April). As described below, the SEP group believes it is likely that yearling production will be substantially greater than the 1.5 per 1,000 spawner rate identified in the objective below; the SEP group believes that choosing the lowest documented yearling-to-spawner ratio known in the Central Valley (Butte Creek) is highly conservative and that this objective should be easily exceeded in a healthy river.

6.3.5.7 Rationale for a Size-at-Migration Life-history Objective

Again, size-at-date of migration was used as a proxy for life-history strategy. The separate timing of migration objective (see above) establishes targets for the duration of the migration timing window, whereas this objective identifies a minimal distribution of size-at-migration among juvenile spring-run Chinook salmon. Production of a broad portfolio of spring-run Chinook salmon sizes during migration is intended to generate at least some spring-run Chinook salmon that are of "optimal" size to capitalize on conditions (throughout their freshwater migration) that exist in a given year. The SEP group recognizes that the size class that will perform best under a given year's set of environmental conditions is not knowable in advance and varies from year to year. Production of a wide portfolio of size-at-migration will ensure that some proportion of the population is appropriately sized to take advantage of conditions in each year (Satterthwaite et al. 2014).

6.3.5.8 Approach to a Size-at-Migration Life-history Objective

For YOY migrants, the SEP group found no reason to expect a different annual size class distribution for spring-run than was expected for fall-run. Run-specific size class distributions may differ at any given time because the two populations spawn at different times; however, over the course of a migration season (the timestep at which this objective is implemented), the overall distribution of size classes should be similar across runs. These minima seem reasonably attainable, based on the size-class distributions currently observed in the river (Figure 7; Table 6) and should capture intended benefits of anticipated habitat restoration activities. Furthermore, it would not be practical to attempt to measure differences in the annual size distribution at migration of spring-run Chinook salmon juveniles versus fall-run Chinook salmon juveniles. If field techniques that allow distinction between juveniles of different runs become available, the SEP group will consider how this objective should be implemented on a run-specific basis.

The yearling production objective was calculated based on the expectation that at least 1.5 yearlings can be produced per 1,000 returning adult females. This was the minimum ratio detected for Butte Creek in the years 2001 to 2007 (Ward et al. 2003, 2004; McReynolds et al. 2006, 2007; Garman and McReynolds 2008, 2009). The rate of yearling production for spring-run detected in Butte Creek is the lowest rate among the populations that have been studied on Sacramento River tributaries (Ward et al. 2003, 2004; Lindley et al. 2004; McReynolds et al. 2006, 2007; Johnson and Merrick 2012). For example, the percentage of yearlings among juvenile spring-run Chinook salmon on Butte Creek ranged from 0.01% to 0.05% during 2001 through 2006 (Ward et al. 2003, 2004; McReynolds et al. 2006, 2007). This compares to approximately 5% of all juveniles being yearlings on Deer and Mill creeks from 1994 to 2010 (Johnson and Merrick 2012). These numbers are believed to underestimate the true proportion of spring-run yearlings present. This was because: 1) capture efficiency for yearling salmon is less than for YOY; and 2) the sampling location was downstream of redds built by fall-run Chinook salmon, which are generally expected to produce a much lower proportion of yearling migrants than spring-run Chinook salmon.

Thus, the SEP group expects the yearling productivity objectives to be easily attainable in a restored Stanislaus River. However, because there is a lack of information on yearling production rates for the Stanislaus River (because spring-run escapement has only been sporadically monitored or documented; Franks 2012), there was no evidence to justify a higher yearling production rate. Failure to attain this objective will strongly suggest some impediment to yearling production in the Stanislaus River that should be investigated and addressed. If, over several years, the yearling to spawner ratio is higher than the very low level targeted here, it is recommend to increase the objective to account for the higher capacity to produce the yearling life-history type.

This yearling production objective will be in place any time spring-run Chinook salmon are spawning on the Stanislaus River. However, it may only be a measureable objective when spring-run Chinook salmon escapement and spawning are sufficient to produce a number of yearlings that can be reliably detected. Assuming yearling production of at least 1.5 per 1,000 returning adult females and that 60% of escapement are females (as per the current estimate for fall-run Chinook salmon, see SEP group calculations for fall-run productivity objective), and a sampling efficiency for yearlings similar to that for Butte Creek (the system from which the minimum yearling/spawner expectation is derived), it is estimated that total escapement of approximately 5,600 spring-run Chinook will be necessary to detect if this objective is not being met. When escapement is lower than this target, the objective should be revised such that at least one yearling is detected any time that spring-run escapement is greater than 1,100 fish. Yearling-sized fish are currently detected in the RSTs of the Stanislaus River (Watry et al. 2007), despite the fact that since the installation of the VAKI RiverWater weir run by FISHBIO, the cumulative number of spring-run Chinook salmon escapement (2007 to 2012) has not exceeded 70 individuals (Franks 2012).

6.3.5.9 Size-at-Migration Life-history Objective

By year XX, generate a broad size-class distribution of emigrating juveniles such that the annual emigrant size-class distribution as measured at Caswell RST is as follows:

- For YOY migrants, same size distribution minima as for fall-run objective
- For yearling migrants, minimum of 1.5 yearlings per 1,000 female spawners

6.3.5.10 Rationale for a Genetic Objective

Central Valley spring-run Chinook salmon have a unique life-history and physiology, which facilitates their abilities to ascend to higher elevation habitat than fall-run and delay spawning for several months (Healey 1991; Yoshiyama et al. 2001). However, much of this higher elevation spawning habitat is no longer accessible to salmon due to the presence of dams, thus limiting the opportunity for differences in spawning locations between spring- and fall-run Chinook salmon (Figure 2; Lindley et al. 2006; Moyle et al. 2008). In rivers with dams blocking access to historic spawning habitat, such as the Sacramento and Feather rivers, hybridization between spring- and fall-run Chinook salmon has occurred (Banks et al. 2000; CDFG 1998). For creeks where access to historic spawning habitat is not blocked by dams (e.g., Mill and Deer creeks), genetic differences between spring- and fall-run Chinook salmon have been maintained and documented (Banks et al. 2000). Due to the genetic, life-history, morphological, ecological, and behavioral differences between spring- and fall-run Chinook salmon, the two runs are designated as different ESUs and are managed based on these designations (Waples 1991; NMFS 2004; Smith et al. 1995).

One primary way to maintain distinct and heritable life-history characteristics among ESUs is to limit gene flow among ESUs and allow for co-evolved gene complexes to be established and maintained through processes of local adaptation. Providing opportunities for spring-run Chinook salmon reproductive isolation is particularly important for the maintenance of spring-run Chinook salmon populations in rivers where high elevation habitat is blocked by dams.

This objective and rationale are not intended to prescribe or preclude the introduction of individuals with a spring-run Chinook salmon genetic lineage (e.g., from current spring-run ESU populations). Rather, it is possible that genetically distinct (from fall-run Chinook salmon) spring-run Chinook salmon are recolonizing San Joaquin River tributaries on their own (or were never entirely extirpated), and are also part of a large reintroduction effort on the mainstem San Joaquin River downstream of Friant Dam that may result in additional colonizations of the San Joaquin tributaries in the future. The intent of this objective is to promote the recolonization of the San Joaquin River and its tributaries and the long-term success of individuals that exhibit spring-run life-history characteristics independent of their near-term genetic origin.

6.3.5.11 Approach to a Genetic Objective

Gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations

(Lindley et al. 2007; HSRG 2014).

6.3.5.12 Genetic Objective

Establish conditions in the Stanislaus River that support spring-run Chinook salmon spawning success and reinforcement of long-term genetic integrity as measured by:

- Greater than 98% of spring-running Chinook salmon spawn with other spring running salmon

6.4 Central Valley Steelhead

6.4.1 What is the Problem?

The number of steelhead in the San Joaquin River basin's three major tributaries, the Stanislaus, Tuolumne, and Merced rivers, is at very low levels (McEwan 2001). Unlike Chinook salmon, there is no dedicated escapement survey for steelhead. However, counts at weirs on these rivers all show only a few adult steelhead returning in any given year, and no fish returning in some years. The species does exist in larger numbers as the resident rainbow life-history form in the tailwaters below the major rim dams, but the anadromous, ESA-listed form of *O. mykiss* is currently extremely rare.

6.4.2 What Outcome(s) (Central Valley Goals) Will Solve the Problem?

Abundance. The CVPIA (Section 3406 of the CVPIA, Title 34 of Public Law 102-575) calls for naturally spawning populations of anadromous fish that are double the 1967 to 1991 baseline, within 10 years. State law (CDFG Code § 6902(a)) and water quality regulations (SWRCB 2006) express the same target.

Productivity and Life-history Diversity. Improvements in Central Valley productivity (measured as parr survival and smolt production) and increased life-history diversity (i.e., more anadromous adults) are necessary to achieve abundance targets for steelhead in the Central Valley, to maintain fish "in good condition" (CDFG Code § 5937), to achieve acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (McElhany et al. 2000), and to be consistent with other fisheries-related and water management related policies.

Genetic Diversity. For steelhead, as for salmon, concerns about genetic diversity and what is needed to sustain healthy and viable populations revolve around the influence of hatchery production and management (Williams 2006). In the Sacramento River basin, steelhead populations are dominated by hatchery fish, as there are hatcheries on Battle Creek, The Feather River, and the American River. However, as none of the three major San Joaquin River tributaries have a steelhead hatchery, straying of stocked steelhead is not currently a major concern in these rivers. The closest steelhead hatchery to the San Joaquin tributaries is on the Mokelumne River, an eastside tributary.

6.4.3 What Does Solving the Problem Look Like (Central Valley Objectives)?

Abundance. AFRP set a doubling goal of 13,000 naturally produced steelhead, but this only applied to the Sacramento River above the RBDD. This estimate was based on Mills and Fisher (1994), which calculated returns from a combination of RBDD ladder counts, hatchery returns, and estimates based on harvest rates. The NMFS Recovery plan (NMFS 2014) has targets for the minimum number of viable steelhead populations needed for recovery, by watershed and sub-region, but unlike AFRP, does not specify exact abundance numbers by watershed.

Productivity. Although no specific abundance targets have been set, clearly survival of juveniles and adults is currently not sufficient to produce the AFRP target of 13,000 naturally produced steelhead in the upper Sacramento, or even 850 adults in most rivers in the Central Valley. Survival and growth rates need to improve greatly to meet these goals.

Life-history Diversity. The extensive loss of historic spawning and rearing habitat in the Central Valley has led to a near-loss of steelhead in many watersheds. Currently, many rivers in the Central Valley are dominated by the freshwater fluvial, or resident, form, also known as rainbow trout. Reversing this loss of life-history diversity will require extensive habitat improvements, both in the rivers and in the Delta, which will allow for higher production of parr with faster growth rates, greater smolt survival, and higher adult survival. These changes should lead to increases in the proportion of *O. mykiss* population represented by the anadromous form.

Genetic Diversity. Steelhead abundance in the Central Valley is now largely dominated by hatchery fish, all of which are released as age-1 smolts. They seem to increasingly mature after only one year in the ocean, and tend to have low numbers of repeat spawners. This has led to few age-classes of fish present in populations, and an overall loss of diversity within the Central Valley population. There needs to be a marked increase in the natural production of steelhead in Central Valley rivers.

6.4.4 How Much Will this Effort Contribute to Attainment of these Central Valley Objectives (Plan Goals)?

Abundance. The goal for abundance in the Stanislaus River is derived from the NMFS Recovery Plan (NMFS 2014), which states that a viable population at low risk of extinction should have a minimum adult escapement of 2,500 individuals over 3 years, with a minimum effective population size of 500 fish in freshwater (the census size of standing stock; for every one fish returning two fish remain in ocean) (850 escapement in 1 year). This would be measured as a minimum 3-year running average of 850 adult steelhead (not counting sexually immature fish, such as “half-pounders”), with a minimum effective population size of 500 in any given year.

A larger adult escapement would allow for a catch and release steelhead sport fishery in the Stanislaus River, assuming a low level of mortality from hooking and handling. If hooking mortality rates, defined as total catch and release fishing related mortality up to outmigration as kelts, were an average of 15% (Ashbrook et al. 2010), then an escapement of 1,000 wild adult steelhead would allow for 850 fish to survive to the kelt stage. Given the popularity of this species as a sportfish, the final recovery goal should be 1,000.

These levels of abundance are lower than those proposed for fall-run and spring-run Chinook populations because, even in relatively healthy watersheds, steelhead typically do not reach the levels of abundance often seen in salmon populations. While salmon spawning runs often number in the hundreds of thousands to low millions, healthy wild steelhead runs typically reach hundreds in smaller coastal streams, thousands in larger rivers, and up to tens of thousands of fish in major river systems of the Northwest and northern California (Busby et al. 1996). Historically, steelhead numbers were certainly much greater, but given the large differences in their life-history, probably never approached the range of salmon, whose numbers commonly numbered in the millions in larger watersheds.

Productivity. Riverine survival levels sufficient to produce enough smolts for a viable steelhead population.

Life-history Diversity. The goal is to support the fullest expression of *O. mykiss* life-history diversity in order to increase population stability, resiliency, and productivity. Currently, the San Joaquin River basin's tributaries are dominated by the resident form of *O. mykiss*, so there is a need for these populations to express more anadromy to meet NMFS recovery goals for steelhead.

Genetic Diversity. Independent populations should be largely free from the influence of hatchery strays. This is a minor issue in the San Joaquin River and its tributaries as there are no steelhead hatcheries present.

6.4.5 What Suite of Species-specific Outcomes (Biological Objectives) Characterize Success?

The biological objectives the SEP group has set for steelhead differ in many respects from those for Chinook salmon. This is partly due to the simple fact that steelhead is a different species with a different, and more complex, life-history strategy. A timeline of the various migration and rearing periods for various *O. mykiss* life stages and age classes is presented in Figure 9.

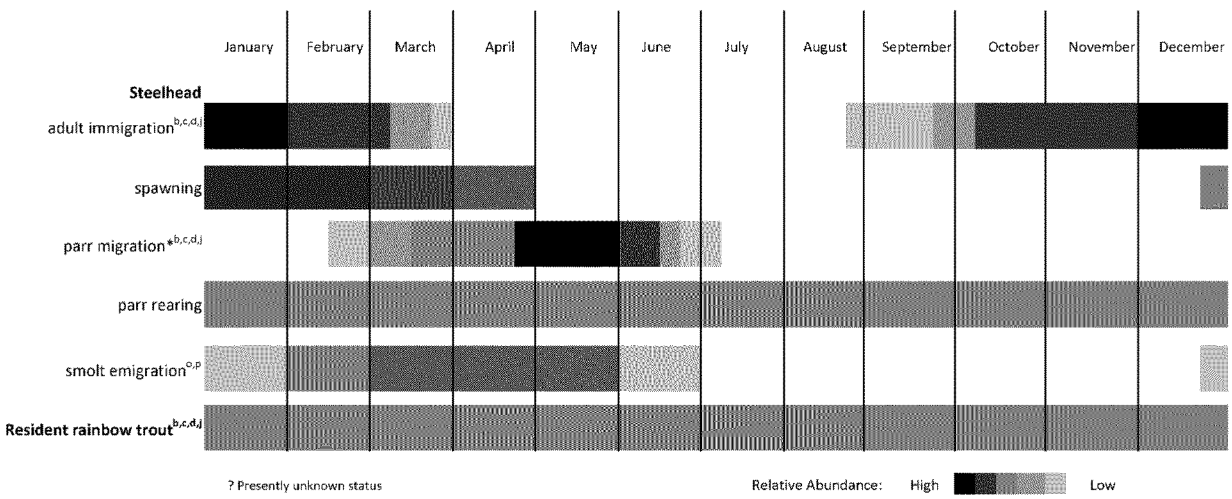


Figure 9

Timeline for *O. Mykiss* Migration and Rearing Periods in the San Joaquin River Basin

Note:
Migrating parr are not true smolts, they might be moving downstream to find suitable rearing habitat, and it is unknown if they contribute to adult returns.

Sources:

a	Moyle 2002
b	Workman 2001
c	Workman 2003
d	Workman 2005
e	Meyers et al. 1998
f	Yoshiyama 1998
g	Williams 2006
h	Merz and Setka 2006
i	Healey 1991
j	Watry et al. 2009
k	Merz and Saldate 2007
l	Snider and Titus 1996
m	Seesholtz et al. 2004
n	Fish management work group
o	NMFS analysis of 2003 to 2011 USFWS data
p	Oakdale RST data (collected by FISHBIO) summarized by John Hannon (U.S. Bureau of Reclamation)

It is also a result of the situation that little data exists on their abundance and none at all on their age structure, growth rates, or survival rates. Nonetheless, it is clear that steelhead, the anadromous form of *O. mykiss*, are greatly underrepresented in the Stanislaus River, and it will require large improvements in both river and Delta habitats to reach suitable levels of abundance, productivity, and diversity. The overall objective for this species in this San Joaquin River tributary is to establish abundant, diverse, naturally reproducing populations of both anadromous and resident fish, with enough resiliency to withstand drought conditions and the effects of climate change.

6.4.5.1 Rationale for Productivity Objectives

In order to count as one of the two independent, viable populations of steelhead in the San Joaquin River basin called for in the NMFS Recovery Plan (NMFS 2014), it must be a naturally produced population at low risk of extinction.

To achieve desired smolt production levels while maintaining a strong resident rainbow population, a larger number of age-0 *O. mykiss* need to be produced. Currently, there are very few present in the canyon reaches below Goodwin Dam, and the downstream extent of rearing likely limited by lack of appropriate substrate, low flows, and high water temperatures. Improved spawning and rearing habitat should boost the abundance of age-0 fish.

The faster growing juveniles in a population typically smolt at younger ages, as long as they reach approximately 140 mm FL by the spring (Seelbach 1993). Large smolts have been shown to have higher survival to the adult stage (Ward et al. 1989). Currently, through-Delta survival rates of steelhead are not well known, and have often been assumed to be low (e.g., 10% in NMFS 2012a). However, recent acoustic tagging studies suggest that survival may be much higher, as results from a recent 6-year study have estimated through-Delta survival rates at 52% in 2011 and 27% in 2012 (Brandes 2014). This study used large hatchery steelhead, which might account for these relatively high rates, but they are much higher than survival rates from studies on Chinook salmon, which also used large hatchery smolts.

The growth rates of juvenile *O. mykiss*, as well as the timing of growth, can vary greatly among watersheds in California. Sogard et al. (2012), using passive integrated transponder (PIT) tag mark-recapture methods, found that juveniles in two central coastal streams, Scott Creek and Soquel Creek, grew very slowly during the dry summer and fall months (0.11 mm/day (0.004 in/day) and 0.14 mm/day (0.006 in/day),respectively). These streams had faster growth rates for fish during the winter-spring months (0.24 mm/day [0.009 in/day] and 0.21 mm/day [0.008 in/day]), when flows were relatively high, even though water temperatures were colder. In contrast, lower Mokelumne River juvenile steelhead grew faster in the summer and fall months (0.46 mm/day [0.018 in/day]) than in the winter-spring (0.60 mm/day [0.024 in/day]). Lower American River juveniles grew at an incredible 1.12 mm/day (0.044 in/day) in the summer-fall months, likely due to the warm water temperatures and high food production in that system, and still grew at 0.61 mm/day (0.024 in/day) in the winter-spring months (Sogard et al. 2012). Stream flows, water temperatures, and food production can clearly interact to produce wide-ranging growth rates in the same life-stage of this species in different seasons of the year.

This minimum length would provide confidence that the smolts being produced have a good chance of surviving to become spawning adults (Bond et al. 2008; Ward et al. 1989). If the smolts produced were very small, around 120 mm to 150 mm (4.7 in to 5.9 in), survival to maturity would likely be extremely low. Steelhead are much more a riverine rearing species than salmon, typically rearing in the river for one to three years, and emigrating from the river as full smolts. There is little evidence that steelhead rear for any length of time in the Delta in its current state, so the SEP group assumed smolt size increase was very small once fish emigrate from the Stanislaus River.

Even at good smolt-to-adult return rates, a minimum number of smolts are needed to achieve the global steelhead abundance goal. High smolt production may also help swamp predators in the lower river and Delta and result in increased survival.

Stream conditions should be suitable for successful spawning and incubation of eggs and alevins.

6.4.5.2 Approach to Productivity Objectives

The NMFS Recovery Plan (NMFS 2014) has a minimum escapement value of 850 fish for a viable population at low risk of extinction. For the Stanislaus River, abundance targets were set for steelhead using this number as a basis, with a slight buffer added for potential mortality from angling. However, counts of juvenile steelhead are very low in the Stanislaus River, and it is known that RSTs do not efficiently capture steelhead smolts. To overcome this data limitation, alternative methods of measuring steelhead productivity are proposed, including measures of parr density and growth rates, smolt size, and smolt production.

In the near future, a steelhead population model for the Stanislaus River may be available, which would allow for the setting of age- and stage-specific survival rates for both in-river and through-Delta reaches. A similar survival methodology for steelhead escapement could be used as was developed for fall-run Chinook salmon escapement described above, but with a goal of 1,000 adults. Since there is not much data on *O. mykiss* from RSTs, survival rates in the model could be estimated at key life stages, including:

- Adults (with fecundity regressions to calculate egg production)
- Age-0 parr (summer time)
- Age-1 smolts (spring time)

- Age-1 parr (summer time)
- Age-2 smolts (spring time)

6.4.5.3 Productivity: Monitoring Requirements

6.4.5.3.1 Parr Density

The density of juvenile *O. mykiss* shall increase over time to one age-0 individual per square meter or 20,000 per river km (0.62 mile), on average, in specified reaches, by year 10. This could be measured though snorkel surveys, electrofishing, or other appropriate sampling techniques.

Snorkel surveys on the Stanislaus River (Kennedy 2008) have shown very low densities (0 to 0.15 per square meter) of age-0 *O. mykiss* in most locations, with a location near Goodwin showing higher densities (0.30 per square meter). Bergman (2014) estimated 0.63 to 2.13 fish per linear meter (3.28 ft) in the Stanislaus River in a reach just below Goodwin Dam.

Kozlowski (2004) electrofished 19 sites on the lower Yuba River and estimated that there was an average of approximately 0.40 age-0 *O. mykiss* per square meter, with a range of 0 to 2.49. Even this density is very low compared to populations in coastal California streams, where average densities of over two fish per square meter are common in electrofishing surveys (Sogard et al. 2006).

To achieve the same total abundance, one age-0 *O. mykiss* per square meter translates to roughly 20,000 per river km (0.62 mile), assuming a river averaging 20 meters (65.6 ft) wide.

6.4.5.3.2 Parr Growth Rates

The growth rates of individual age-0 and age-1 *O. mykiss* shall increase over time to 0.60 mm/day (0.024 in/day) by year 10. An exception to this requirement shall be at age-0 densities over 2 per square meter on average, or 2,000 per river km, on average, at which growth rates could be as low as 0.40 mm/day (0.016 in/day), to allow for lower growth rates at high juvenile densities. This could be measured by capturing, PIT tagging, and recapturing juvenile *O. mykiss* in the river. Additionally, parr growth rates could be back-calculated using scale analysis, as hook and line sampling is biased toward catching larger fish.

This rate is intermediate between the lower Mokelumne River, which has colder water temps and smaller invertebrates than the lower American River, which has extremely fast growth due to warm water temps and good invertebrate production.

6.4.5.4 *Productivity Objectives*

6.4.5.4.1 Smolt Size

The life stages of *O. mykiss* are as follows:

Stage No.	Stage Name	Stage Description
1	Egg-sac fry	Newly emerged, still has egg yolk visible
2	Fry	Small parr, only a few weeks old
3	Parr	Distinct parr marks, scales not silvery
4	Silvery parr	Scales slightly silvery
5	Smolt	Bright silvery scales, dark edges on caudal fin
6	Adult	Sexually mature fish

At least 90% of the smolts (stage 5) observed in the lower Stanislaus River should be 150 mm (5.9 in) FL or greater in length. Current technology for measuring steelhead smolt production in large rivers is limited, especially rivers with high and turbid spring flows. Steelhead smolts are believed to be strong enough swimmers that they can avoid capture in RSTs. The most successful methods for counting smolts have been inclined-screen traps and video cameras, which require some type of structure, such as a weir or low-head dam to concentrate fish and allow for individuals to be captured or filmed. Potential future technologies include next-generation Didson cameras (ARIS) and mark-resight estimates based on PIT tagging of age-0 or age-1 fish prior to smolt emigration, combined with mobile PIT tag antennae.

6.4.5.4.2 Smolt Production

The number of naturally produced smolts (stages 4 and 5) greater than 150 mm (5.9 in) FL per adult female steelhead shall be at least 165 by year 10 of the implementation of habitat restoration. This could be measured either at Caswell or another suitable location further downstream, but prior to the confluence with the mainstem San Joaquin River. The methodology would be the same as for smolt size, but would not necessarily require that smolts be captured, only observed well enough to be identified and counted.

6.4.5.4.3 Parr and Smolt Survival

90% of all the silvery parr and smolts (stages 4 and 5) counted at (the lower end of the gravel bedded reach) must be detected at (the lower river/beginning of Delta).

6.4.5.4.4 Adult Spawning

When adult steelhead are present and spawning, their eggs will have a minimum egg to emergence survival rate of 35% (measured by surrogates [e.g., egg trays] and/or as projected by monitoring of temperature, flow, sediment deposition, and scour). This could be measured with egg survival studies (implant eggs and measure survival in time and space). As proxies for egg survival, redd construction, temperatures, flows, intra-gravel flows, and DO levels can be monitored.

6.4.5.5 Rationale for Life-history Objectives

Age-0 *O. mykiss* have not yet selected a life-history pathway (anadromy or residency), (Thorpe et al. 1998; Beakes et al. 2010). Tracking the proportion of those that eventually smolt is one measure of the life-history diversity of the *O. mykiss* population. In a population dominated by the resident form, nearly all will choose to mature in the stream as residents, due to generations of selective pressure against anadromy, likely from some combination of low smolt survival, large asymptotic size, and/or high survival rates of adult residents (Satterthwaite et al. 2009).

The proportion of anadromous adults in the Stanislaus River appears to be very low currently. Another measure of the balance between resident and anadromous forms could be made at the adult stage.

There are several factors that are likely contributing to this low production of anadromous individuals. The river habitat may not be producing many age-0 *O. mykiss*, and those that are produced may be growing slowly or have poor survival. Delta habitat conditions may result in low smolt survival. Improving smolt survival from the lower Stanislaus River through the Delta will likely require a combination of the production of larger smolts and significant habitat restoration in both the rivers and the Delta.

In rivers with healthy wild steelhead populations, the majority of juveniles tend to be produced by anadromous mothers, even if there are female resident rainbow present (Donohoe et al. 2008). The sex ratio of adult resident *O. mykiss* tends to be heavily biased toward males (Rundio et al. 2012), and genetic parentage analysis has shown that resident males contribute more to the next generation of steelhead than resident females (Christie et al. 2011), which is not surprising as resident males are predicted to be more abundant in species with partial anadromy (Jonsson and Jonsson 1993).

This objective seeks to maintain a minimum number of adult residents to allow the continuation of the popular sport fishery in the lower Stanislaus River, as well as creating a "refuge population" of *O. mykiss* in the river that can potentially give rise to anadromous progeny. The current number of fish in a specified size range could be estimated through snorkel surveys. Based on this information, the desired number of adult residents needed to support the sport fishery could be established as a fraction of the estimated population size. The value set could be 75% for example. This approach is based on the assumption that an overall boost in production of *O. mykiss* would at least partially offset the shift toward anadromy.

6.4.5.6 Approach to Life-history Objectives

These biological objectives for steelhead use different metrics to measure, sometimes directly, sometimes indirectly, the proportion of the *O. mykiss* population that is anadromous versus resident. The SEP group acknowledges that there is no method available to determine the future migratory life-history of individual *O. mykiss* parr in the river. Therefore, the general approach adopted was to boost overall productivity of juveniles, and increase individual growth rates and survival rates in the river. In concert with increased smolt to adult survival rates in the lower San Joaquin River and the Delta, this should lead to higher numbers of juveniles following the anadromous life-history strategy (Satterthwaite et al. 2010).

6.4.5.7 Life-history Objectives

6.4.5.7.1 Anadromy – Juvenile Stage

A minimum of 150 steelhead smolts shall be produced per female spawner in the poorest water years up to a minimum of 300 per female spawner in good water years. This shall be tracked on a brood-year basis, as smolt-years in steelhead do not necessarily match brood-years. Measurement of how well this objective has been achieved will require accurate estimates of adult escapement and smolt production each year for several years, plus ages of smolts in order to assign brood years.

6.4.5.7.2 Anadromy – Adult Stage

The proportion (as a 5-year running average) of all counted adult *O. mykiss* over a full season shall be a minimum of 25% resident (less than 460 mm [18.1 in] FL), counted during the summer or fall) and 20% anadromous (greater than 460 mm [18.1 in] FL) individuals (counted during the spawning migration). Stream resident adults could be counted by snorkel surveys or estimated by mark and recapture through hook and line sampling. Anadromous adults could be estimated at a weir, snorkel surveys, or redd surveys.

6.4.5.7.3 Anadromy – Maternal Origin

The proportion of age-0 *O. mykiss* that are the progeny of anadromous mothers shall increase to a minimum of 45% by year 15. This percentage could be met even with approximately ten times more resident adults (approximately age-3 and older) than adult steelhead.

Methodology. There are several published papers that have used otolith microchemistry to determine the maternal origin of individual *O. mykiss* (Donohoe et al. 2008; Zimmerman et al. 2009). For this type of study, it is best to take otoliths from age-0 fish, to avoid biases from sampling older fish that have decided to become resident, as it is known that anadromy in *O. mykiss* has some genetic heritability.

6.4.5.7.4 Anadromy – Balance

Maintain a minimum resident (as defined by a combination of rear-round presence, size at age, and scale analysis) adult population abundance that at least meets the lower end of the abundance range (i.e., a superpopulation of 1,492 to 7,873 age 1+, or 3 to 9 age 1+ per 100 m^2) specified by Bergman et al. (2014). Resident adult numbers can be estimated by mark-recapture studies, snorkel surveys, or electrofishing. Alternatively, a creel survey could estimate catch rates by anglers.

6.4.5.7.5 Anadromy – Smolt Emigration

In most steelhead populations, the largest, oldest smolts (often age-3) emigrate first, followed by the smaller, younger smolts (age-2 and age-1) as the emigration progresses. In order to maintain this age-class diversity among smolts, environmental conditions should be suitable for smolt emigration for several months of the year. Steelhead smolts have been detected emigrating from the Stanislaus River anywhere from December through June, based on data from the Caswell and Oakdale RSTs, though the abundance of smolts is usually greatest from January through April. As an objective, the Stanislaus River RSTs should detect emigrating steelhead smolts (classes 4 [silvery parr] and 5 [smolt] of at least 150 mm [5.9 in] FL in a minimum of 4 months of each emigration season (October through September).

7 ENVIRONMENTAL OBJECTIVES

The environmental objectives developed by the SEP group are intended to represent environmental conditions needed to support and further expand Chinook salmon and steelhead populations within the San Joaquin River basin. Simply stated, they define the physical and chemical conditions needed to attain the biological objectives. They also provide life-stage specific guidance that should be used in the development and prioritization of conservation measures.

Timing is an important aspect of the environmental objectives. They must be attained before the related biological objective can be met. Also, it is not intended that producing these necessary conditions will substitute for attaining the biological objectives. In other words, attainment of the biological objectives is the ultimate goal, and the environmental objectives should result in achievement of the goal, but may have to be adjusted to fully meet the goal.

The environmental objectives have been developed for the following categories:

- Adult upstream migration
- Adult holding
- Spawning
- Egg incubation
- Juvenile rearing and migration

The specific criteria for each environmental objective and category are detailed in this section and summarized in Appendix A based on a limiting-factors matrix for the categories or life-cycle components. Temperature, DO, and contaminants are critical to all life stages. These parameters are discussed by lifes stage in this section and a more integrated discussion of temperature, DO, and contaminants is provided in Appendix B. A general approach for and the intended application of the environmental objectives are presented below. Descriptions of key variables that describe the objectives in further detail and the basis for selected criteria are also presented below.

7.1 General Approach for, and Intended Application of, Environmental Objectives

Environmental objectives are intended to quantify the desired habitat and ecosystem conditions in the planning area (e.g. Stanislaus River) necessary to achieve and sujstain the biological objectives. Environmental objectives are defined in terms of a range of specific measurable parameters that together make up suitable environmental conditions for the species in question. Because habitat and ecosystem condition needs vary across species as well as among different life-history stages within a single species, environmental objectives are defined separately for each species/life-history stage combination. For ease of comprehension and integration, and because multiple species/life-history stages occupy the river simultaneously, to the extent that there is overlap between the habitat and ecosystem needs of different species/life-history stage pairings, the same parameters have been used to quantify those needs.

In general, and specifically in the application of environmental objectives to the development of conservation measures, it is important to note that the success of all life-history stages is necessary to achieve the biological objectives. As a result, though environmental objectives are specified by specific life-history stage, attaining the biological objectives related to that life-history stage will require that environmental objectives for all life-history stages for the species be achieved.

Because different species/life-history stage combinations have different habitat needs and occupy the river at different times, environmental objectives for each species/life-history stage have been assigned a) a timing window indicating the months of the calendar year during which the conditions described by the objectives should be maintained and b) a geographic range (defined by reach) where the objectives are applicable. It is important to note that environmental objectives do not necessarily need to be met across the full specified geographic range in order to achieve biological objectives. Rather, the geographic range merely indicates those reaches where sufficient spatial habitat extent (quantified as a component of environmental objectives where applicable) can be achieved, given inherent characteristics of the system (e.g. geologic, topographic, and geomorphic). Geographic ranges have been defined as broadly as possible to allow for maximum flexibility in the attainment of environmental objectives given the inherent constraints of the system.
In some cases, for some portion of the applicable timing window or during some years, only a subset of the optimal conditions for a given species or life-history stage may be attainable.

However, this does not necessarily indicate that an individual or cohort experiencing those sub-optimal conditions will not contribute to population success or the attainment of biological objectives. For this reason, for all applicable parameters, environmental obvjectives have been defined in terms of three different categories of condition:

- Optimal conditions
  - Contribute to the health and growth of individuals and the population without harmful effects.
  - Support the attainment of the biological objectives
- Sub-optimal conditions
  - Associated with some degree of impact at the individual or population level (e.g. observable/measurable stress, increased vulnerability to disease, reduced growth, reduced survival)
  - May or may not support attainment of the biological objectives
    - Where likelihood of detriment increases with lower suitability (relative to optimal range), or decreased occurrence (frequency or duration) of suitable conditions
- Detrimental conditions
  - Associated with a significant level of harm at the individual or population level
  - Do not support and are a detriment to the attainment of one or multiple biological objectives

It should be noted that in some cases, a limited degree of stress can be beneficial to a species. Optimal conditions were established to be broad and attainable and to encompass those stresses that are supportive of both individual and population health and fitness. Sub-optimal conditions, by contrast, if maintained for an extended period or experienced across multiple parameters should be considered harmful and will inhibit the potential for the species/life-history stage experiencing them to cointribute to the attainment of the biological objectives for that year class.

When looked at in their totality, the complete set of environmental objectives effectively provide a spatially and temporally explic depiction of the system that will support the attainment and maintenance of the biological objectives, environmental objectives are thus intended to serve as the basis for the development and evaluation of conservation measures designed to create the habitat and ecosystem conditions necessary to support biological objectives. It therefore follows that acheiving the biological objectives will necessitate a suite of conservation measures that together address all environmental objectives. In cases where it has been provided, the required spatial extent of the habitat conditions specified in the environmental objectives is a function of population size and fish density relative to habitat area relationships and has been calculated based on the target population size. As a result, prior to biological objectives being achieved, while populations are growing, the full spatial extent may not be required in order to make progress towards those objectives. However, in order to support biological objectives Conservation Measures should be implemented that result in habitat spatial extent that consistently exceed the needs of the current population size.

Additionally, prior to achieving desired environmental conditions, habitat conditions may be less optimal for certain species/ life-history stages than for others. Resolving the conditions for one life-history stage may therefore have a disproportionately large effect on the ability to advance biological objectives for other or all of that species' life-history stages. To inform prioritization of Conservation Measures section XX provides guidance on the relative impact of existing stressors on life-history stages.

Given the dynamics and needs described above necessary to achieve biological objectives, the SEP group anticipates the need for a Conservation Plan that: a) encompasses a suite of conservation measures designed to achieve all environmental objectives; b) provides a phased implementation approach for those objectives through time; and c) prioritizes the sequence for implementation based, in part, on the relative needs of different life-history stages and the evolving habitat extent of the growing population.

7.2 Environmental Objectives and Supporting Rationale for each Life Stage

7.2.1 Adult Upstream Migration

Chinook salmon and steelhead return from the ocean to fresh water in order to spawn in the rivers of the Central Valley. Fall-run Chinook salmon return to San Joaquin River tributaries, including the Stanislaus, between late September and December (this is a narrower window than is observed among fall-run Chinook salmon returning to the Sacramento River and its tributaries). Spring-running Chinook salmon have been observed in San Joaquin Tributaries in recent years and are being restored to the mainstem San Joaquin under the San Joaquin River Restoration Program; these fish are expected to migrate to their spawning grounds between March and June (SJRRP 2010). Central Valley steelhead migrate upstream from September through April.

After spawning, Chinook salmon adults will die, whereas steelhead may attempt to return to the estuary and ocean for possible repeat spawning in subsequent years. Both Chinook salmon and steelhead cease to eat during their spawning migrations; somatic energy reserves and nutrients are used to complete the upstream journey, the processes of attaining and defending nest sites and mates, and spawning. Nutrients and energy are also allocated to production of gametes. Adult migration and gametogenesis are energy-intensive and time-sensitive activities; thus, delays caused by barriers or disorientation can result in death, lost opportunities to spawn, or other form of reduced reproductive success.

Chinook salmon and steelhead typically return to their natal streams to reproduce, a process called "homing" and its opposite (i.e., returning to a non-natal stream to spawn) is called straying. Several modes of orientation play a role in successful homing; however, once adult fish enter freshwater, olfactory identification of water emanating from the natal stream is the dominant cue driving salmonid orientation (Healy 1991; Quinn 2005). In highly managed watersheds like those of the Central Valley where large fractions of a river's flow may be diverted at one or more locations along the migration path, homing success can be influenced by both the amount of flow from a particular spawning stream that reaches migrating adult salmon and the ratio of flow from various source streams in a watershed (Marsten et al. 2012). The magnitude of pulse flows or attraction flows to facilitate juvenile and adult migrations, and the ratio of flows from various San Joaquin River tributaries that must reach any point along the migratory corridor, are not addressed as environmental objectives here because establishing such San Joaquin River basin-wide objectives will require completion of environmental and biological objectives for all the major San Joaquin River tributaries and the mainstem. Likewise, base flow conditions in the Stanislaus and mainstem San Joaquin below its confluence with the Stanislaus are not identified here. At a minimum, environmental objectives for base flows are expected to be those that will result in attainment of optimal conditions for other environmental conditions (as described below).

Environmental objectives that are required for successful completion of adult migrations (from freshwater entry to arrival at holding sites (for spring-run Chinook salmon) or to spawning grounds (for fall-run Chinook salmon and steelhead) include those for temperature, DO, and the minimum depth of the critical riffle. In addition, contaminants (both metals and pesticides) can interfere with migration success and/or subsequent reproductive success; maximum tolerable levels of these compounds that affect completion of the salmonid life cycle (including migration) are also identified. Although, adult Chinook salmon and steelhead probably have different environmental requirements for optimal performance, such differences were not apparent in the literature; thus, all environmental objectives for adult migration apply to both runs of Chinook salmon and steelhead.

Poor environmental condition may result in delay of spawning migrations rather than outright mortality. Delayed migrations are expected to negatively affect reproductive success. Consistent with this expectation are the observations that adult (sockeye) salmon migrate at speeds much faster than those that would be energetically optimal (Brett 1983) and that fat reserves are largely depleted by the time fish spawn and die (as reviewed in Quinn 2005). This document assumes that "optimal" conditions for adult migration are those that result in no delay (i.e., 0-hours delay) in the migration process and "sub-optimal conditions" will result in delays that are less than 24 hours. Environmental conditions that result in migration delays greater than 24 hours are considered to be "detrimental" to attainment of biological goals and objectives for the Stanislaus River; delays of greater than 24 hours may result in reduced ability to acquire and defend spawning territory, mates, or completed redds. In addition, environmental conditions that result in extended delay of migration are likely to be associated with stresses that affect fecundity (e.g., egg or sperm viability).

A summary of the environmental objectives detailed below for the adult upstream migration life stage is provided in Table A-1 (Appendix A).

7.2.1.1 *Temperature*

7.2.1.1.1 Rationale

Water temperature affects all aspects of salmonid metabolism and physiology. Low water temperatures are not likely to be a problem for migrating Central Valley salmonids. High water temperatures approaching physiological limits occur with some frequency in most of the larger Central Valley Rivers (Williams 2006). These temperatures result in high metabolic rates and increased susceptibility to disease (USEPA 1999, 2003; NRC 2004). In addition, increases in temperature reduce the ability of water to hold DO, which may stress migrating salmonids. Finally, development and maintenance of gametes appear to be negatively affected by prolonged exposure to elevated temperatures (Berman 1990 and Berman and Quinn 1990 as cited in USEPA 1999).

7.2.1.1.2 Approach

Several literature reviews provide insight into temperature levels that are optimal, sub-optimal, or detrimental to the success of migrating adult Chinook salmon and/or steelhead. The SEP group relied primarily on USEPA (1999; 2003) guidance for temperature effects on Pacific salmon and supplemented that information when newer information and/or studies specific to Central Valley salmon were available. Wherever possible, temperature thresholds are reported as both a daily average (corresponding roughly to the temperature threshholds reported from studies using constant temperature conditions) and 7-day average of daily maximum temperatures (7DADM) as per the practice of the USEPA (2003). The 7DADM that corresponds to a daily threshold was calculated by adding one half of the difference between daily average and daily maximum temperatures (USEPA 2003) to the daily threshold reported in the literature; for the Stanislaus River, this correction factor was estimated to be 1.5°C (2.7°F) (i.e., the average difference between daily average and daily maximum was approximately 3°C (5.4 °F), so 1.5°C (2.7°F) was added to any daily recommended temperature threshold to estimate the "midpoint" temperature for the corresponding 7DADM). For some temperature-related effects, other temperature metrics are reported when the effect occurs on a shorter or longer timeframe. Sub-optimal conditions were those associated with negative, sub-lethal effects.

7.2.1.1.3 Objectives

Raliegh et al. (1986) identified weekly average optimal temperatures of 8°C to 12°C (46.4°F to 53.6°F) for Chinook salmon; however, USEPA identified no sub-optimal impacts at constant temperatures lower than 14°C (57.2°F). Optimal temperatures range from 9.5°C to 15.5°C (49.1°F to 59.9°F) as a 7DADM (accounting for the typical difference between daily average and daily maximum temperatures in the Stanislaus River).

Sub-optimal temperatures (those associated with negative sub-lethal effects) ranged from constant laboratory temperatures of 14°C to 19°C (57.2°F to 66.2°F) or 15.5°C to 20.5°C (59.9°F to 68.9°F) as a 7DADM. Exposure to high water temperatures facilitates infection among migrating adult salmonids (Noga 1996). USEPA (2001) identified an elevated risk of disease spread at weekly average temperatures between 14°C to 17°C (57.2°F to 62.6°F) and USEPA (2003) identifies high risk of infection at prolonged exposure to temperatures greater than 18°C (64.4°F). USEPA (2003) reported reduction in migration fitness due to cumulative stresses associated with prolonged exposure to temperatures 17°C to 18°C (62.6°F to 64.4°F). Swimming performance is reduced at temperatures greater than 20°C (68°F) (USEPA 2003) but, Williams (2006) and Richter and Kolmes (2005) indicate that migration may be impeded when temperatures are as low as 19°C (66.2°F). Many sources recommend maintaining temperatures less than 20°C to 21°C (68°F to 69.8°F) to prevent direct impairment of Chinook salmon migrations (Richter and Kolmes 2005; USEPA 1999, 2003). Furthermore, although the impact of water temperatures on developing embryos is not well understood, there is evidence that developing reproductive tissues exposed to high temperature may be less viable than those that are formed under cooler temperatures. USEPA (2003) indicates that eggs in holding females exposed to constant temperatures greater than 13°C (55.4°F) suffer reduced viability. Berman (cited in USEPA 1999) found that offspring of adult Chinook salmon that had been held for 2 weeks at temperatures between 17.5°C to 19°C (63.5°F to 66.2°F) had higher pre-hatch mortality and developmental abnormality rates and lower weight than a control group. The SEP group's 7DADM of 15.5°C to 20.5°C (59.9°F to 68.9°F) reflects the thresholds for sub-optimal effects, including delays in adult migration that would exceed 24 hours.

Detrimental temperatures are those that will tend to prohibit attainment of biological objectives for the Stanislaus River. The Incipient Upper Lethal Temperature (IULT) for

Chinook salmon may be as low as 21°C to 22°C (69.8°F to 71.6°F) for both adult Chinook salmon and steelhead during migration (USEPA 1999, 2003; Richter and Kolmes 1995). Williams (2006) reported that salmon returning to the Stanislaus River in 2003 endured water temperatures greater than 21°C (69.8°F) on their migration; however, there is no indication that these fish spawned successfully or that they produced viable offspring. Given the range of detrimental effects to migrating adult salmon and steelhead and their future offspring, and the different exposure timesteps in which these negative effects would be expected to occur, the SEP group provides several thresholds for detrimental temperature effects. Weekly mean temperatures greater than18°C (64.4°F) expose migrating salmonids to a high risk of disease, which could lead to catastrophic failure of a year class (e.g., NRC 2004). On a 7DADM basis, temperatures greater than 20.5°C (68.9°F) must be avoided in the migration corridor. Instantaneous temperatures (e.g., daily maxima) must be below 22°C (71.6°F) to avoid detrimental effects to migrating adult salmon.

Table 11 summarizes the temperature objectives for adult upstream migration for Chinook salmon and steelhead.

Table 11
Temperature Objectives for Chinook Salmon and Steelhead Adult Upstream Migration

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Delta to Holding/ Spawning Grounds	**Fall-run:** Late September to December **Spring-run:** March to June **Steelhead:** September to April	Optimal	8°C to 14°C (46.4°F to 57.2°F) (Daily Average)
			9.5°C to 15.5°C (49.1°F to 59.9°F) (7DADM)
		Sub-optimal	14°C to 19°C (57.2°F to 66.2°F) (Daily Average)
			15.5°C to 20.5°C (59.9°F to 68.9°F) (7DADM)
		Detrimental	> 18°C (64.4°F) (Weekly Average)
			> 19°C (66.2°F) (Daily Average)
			> 20.5°C (68.9°F) (7DADM)
			> 22°C (71.6°F) (Instantaneous)

Notes:
“>” = greater than
“<” = less than
°C°F = degrees Fahrenheit
7DADM = 7-day average of daily maximum temperature

7.2.1.2 Dissolved Oxygen

7.2.1.2.1 Rationale

DO is critical to producing the energy adult salmonids need to complete their upstream migrations. Oxygen consumption increases exponentially with increased swimming velocity (Brett 1964) and, as noted above, adult salmon tend to migrate at speeds approaching their physiological maxima. The capacity of water to hold DO varies inversely with temperature and the concentration of other substances dissolved in the water. In addition, increasing abundance of micro-organisms in the water column generates increasing demand for DO (biological oxygen demand, BOD). High temperatures, high concentrations of dissolved substances, and high BOD each contribute to periodically low levels of DO in the San Joaquin mainstem (e.g., http://www.sjrdotmdl.org/concept_model/about.htm and sources cited there). As a result, areas of the lower San Joaquin River and Delta are listed as being impaired on the USEPA Clean Water Act Section 303(d) list for not meeting water quality standards due to low DO (USEPA 2011); these low levels of DO have been observed to delay or block adult salmon migrations into the San Joaquin River basin during some years (http://www.sjrdotmdl.org/concept_model/about.htm and sources cited there).

7.2.1.2.2 Approach

The SEP group relied on DO criteria established by the USEPA (1986) and the Central Valley Regional Water Quality Control Board (CVRWQCB; 2011) as well as relevant technical literature (e.g., WDOE 2002) to identify DO objectives that are optimal (no negative effects), sub-optimal (observably negative, sublethal effects), and detrimental (preventing attainment of biological objectives) ranges for migrating adult salmonids. The approach the SEP group used to translate available information on impairment levels into optimal, sub-optimal, and detrimental objectives is shown in Table 12.

Table 12
Recommended Cold-Water Species DO Levels for Spawning, Egg Incubation, and Larval Life Stages

Level of Impairment to Embryo and Larvae Stages	Water Column Minimum Average Concentration	Intra-Gravel Minimum Average Concentration	Optimal, Sub-Optimal, Detrimental[1]
No production impairment	11 mg/L	8 mg/L	Optimal

Slight production impairment	10 mg/L	7 mg/L	Sub-optimal
Slight production impairment	9 mg/L	6 mg/L	Sub-optimal
Moderate production impairment	8 mg/L	5 mg/L	Detrimental
Severe production impairment	7 mg/L	4 mg/L	Detrimental
Limit to avoid acute mortality	6 mg/L	3 mg/L	Detrimental

Notes:
[1] Relationship of recommended dissolved oxygen (DO) levels to optimal, sub-optimal, and detrimental levels Identified by the SEP group
Table adapted from USEPA 1986
mg/L = milligram per liter
USEPA 1996

7.2.1.2.3 Objectives

The Washington State Department of Ecology (WDOE; 2002; see also USEPA 1986) reported that DO concentrations above 8 to 9 milligrams per liter (mg/L) are needed for maximum swimming performance in salmon. Several researchers report decreased swimming efficiency at DO less than 7 mg/L (WDOE 2002; Dahlberg 1968 as cited in British Columbia, Ministry of the Environment, Environmental Protection Division[4]). DO levels below 5 to 6 mg/L elicited avoidance (WDOE 2002). Davis (1975) reported a "distress" response when adult salmon were exposed to DO less than 6 mg/L. Hallock et al. (1970) found that adult Chinook salmon migrating up the San Joaquin River avoided DO concentrations below 5 mg/L; however, their observation that these fish began to migrate when DO increased above 5 mg/L is not conclusive evidence that DO levels between 5 to 6 mg/L are acceptable. First, these fish had already suffered an extended delay while avoiding DO levels below 5 mg/L, so this is not an indication that the fish he observed would not have been delayed had they initially encountered DO levels between 5 to 6 mg/L. Second, the final fates and reproductive successes of the fish Hallock et al. observed were not recorded; therefore, it is not known if the eventual migration through waters with low DO had negative fitness consequences.

The regulatory limit for DO in the Stockton Deep Water Ship Channel (DWSC) is 6 mg/L during months when fall-run Chinook salmon migrate; however, that standard applies only to the DWSC, not other waters that San Joaquin River basin fall-run Chinook salmon might migrate through. The standard in other stretches of the fall-run migratory pathway is

[4] http://www.elp.gov.bc.ca/wat/wq/BCguidelines/do/do-03.htm

5 mg/L. Similarly, the standard is only 5 mg/L during the spring (CVRWQCB 2011). Spring-run Chinook salmon adults (which were not known to be present in the San Joaquin River basin when the regulatory standard was implemented) require the same levels of DO as do fall-run Chinook salmon and steelhead are believed to require similar DO levels to complete migration; therefore, the 6 mg/L boundary between sub-optimal and detrimental conditions must apply during the spring migration season as well. DO concentrations above 8 mg/L were assumed to represent optimal conditions and concentrations below 6 mg/L were detrimental. Between 6 and 8 mg/L was identified as sub-optimal for migrating and holding adults.

Table 13 provides a summary of DO objectives for adult upstream migration for Chinook salmon and steelhead.

Table 13
DO Objectives for Chinook Salmon and Steelhead Adult Upstream Migration

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Delta to Holding/Spawning Grounds (Main Channel)	**Fall-run:** Late September to December	Optimal	> 8 mg/L (Daily Minimum)
	Spring-run: March to June	Sub-optimal	6 to 8 mg/L (Daily Minimum)
	Steelhead: September to April	Detrimental	< 6 mg/L (Daily Minimum)

Notes:
mg/L = milligram per liter
“>” = greater than
“<” = less than

7.2.1.3 Channel Depth

7.2.1.3.1 Rationale

Migrating adult salmonids require water of sufficient depth to facilitate upstream passage. Although migrating salmonids can transit areas with water that is less than their body depth, such conditions are not desirable as they cause stresses associated with increased drag and reduced swimming efficiency, low oxygen availability (if gills are exposed), exposure to predators and poachers, abrasion on the river bed, crowding, and the cumulative effect of these negative conditions.

7.2.1.3.2 Approach

Riffles that do not provide depths greater than the body depth of an adult salmon between adjacent pools impede salmon migration. For many decades, the California Department of Fish and Wildlife (2013[5]) has used a protocol for determining minimum depth of the critical (most shallow) riffle, which is applied in higher-elevation waterways to determine necessary instream flows (depth increases with increased flow). The methodology for calculating necessary flows from estimates of critical riffle depth may not be applicable to low gradient, mainstem rivers; however, the criteria for estimating minimum depths and minimum extent of those depths in the shallowest riffle are relevant and likely conservative estimates for mainstem rivers. Indeed, to account for the long distances that migrating salmon must travel in mainstem rivers, the SEP group has modified the DFW criteria to include a longitudinal minimum depth (i.e., addressing depths in riffles up and downstream of the critical [shallowest] riffle).

The critical riffle methodology (as modified by the SEP group) describes the boundary between sub-optimal and detrimental conditions. In other words, this environmental objective describes the minimum allowable depth of the Stanislaus and lower San Joaquin River. An optimal depth profile has yet to be determined and would likely depend on factors such as water temperature, clarity, DO, velocity as well as the density of salmon migrating during any particular period.

7.2.1.3.3 Objectives

1. Shallowest riffle: The shallowest riffle in the migratory corridor (critical riffle) will have a depth of at least 0.3 meter (m) (at least 1 foot [ft]), meaning that at least 10% of the entire length of the transect (perpendicular to flow) must be contiguous with

[5] DFG, 2013. Standard Operating Procedure for Critical Riffle Analysis for Fish Passage in California DFG-IFP-001. Prepared by M.E. Woodard, Quality Assurance Research Group, Moss Landing Marine Laboratories. October 2012, updated February 2013.

depths greater than or equal to 0.3 m (1 ft) and at least 25% of the entire transect must be greater than or equal to 0.3 m (1 ft) (CDFW 2013).

2. Frequency of shallow riffles: 90% of the riffles in the migratory corridor must satisfy the requirements of the critical riffle for depths greater than or equal to 0.46 m (1.5 ft) instead of greater than or equal to 0.3 m (1.0 ft).

7.2.1.4 Contaminants

7.2.1.4.1 Rationale

The Stanislaus River, San Joaquin River, Delta, and San Francisco Bay, have been identified as being impaired on the USEPA Clean Water Act Section 303(d) list by pesticides (SWRCB 2010; USEPA 2011). In addition, mercury and selenium have been identified as impairing beneficial uses in the Stanislaus River, San Joaquin River, Delta, and San Francisco Bay (SWRCB 2010; USEPA 2011). Contaminants have the high potential to adversely impact the successful completion of adult migration throughout the migratory corridor. However, mercury and selenium bioaccumulation in the ocean are likely low and returning adults cease to eat during their migration, so there are low risks to adult salmonid migration from mercury and selenium as adults (though exposure earlier in the life cycle may impair adult performance) (CEDEN 2014c). There is some evidence that other contaminants (e.g., hydrocarbons and metals) from urban runoff has caused pre-spawn mortality in salmonids in the Pacific Northwest (Scholz et al. 2011); however, there is no data suggests that these contaminants are at the levels that would impact upmigratng salmonids to the Stanislaus River. Therefore, pesticides are the only contaminants that have perceived direct impacts on adult migrants in their migration to the Stanislaus River spawning reaches; only pesticide objectives are discussed for this life stage.

Adult fish are typically less sensitive to pollutants than juveniles; however, pre-spawn adult salmonids are likely less tolerant of chemical stressors because they have used most of their accumulated fat stores for gamete production (NMFS 2008, 2010, and 2013b). It is probable that some pre-spawn migrating adults will die as a result of short-term exposures to pesticides, especially when subjected to additional stressors like elevated temperatures. Pre-spawn mortality is a particularly important factor in the recovery of salmonid populations with low abundance because every adult is crucial to the population's reproductive potential and viability (NMFS 2013b).

Successful migration of adult fish may also be impeded by exposures to sub-lethal concentrations of pesticides. For example, most pesticides, in addition to other chemical contaminants like metals, have been found to disrupt fish olfaction (Hansen et al. 1999; Moore and Waring 2001; Scholz et al. 2000). This disruption of the olfactory sensory can eliminate the detection of natal waters or disrupt orientation in adult migrants, which can increase straying (Potter and Dare 2003; Scott and Sloman 2004). Furthermore, pollutants have been found to adjust migration patterns and delay timing in adult migrating Atlantic salmon in the Maramichi River, Canada (Elson et al. 1972).

7.2.1.4.2 Approach

The SEP group relied on adopted numeric water quality objectives for pesticides from the Sacramento and San Joaquin River Water Quality Control Plan, and proposed pesticide water quality objectives from developing pesticide control programs (CVRWQCB 2011, 2014, 2015) to determine pesticide levels that should provide no adverse impacts to adult migration. In addition, for pesticides that do not have state or federally promulgated objectives or criteria, the SEP group used the USEPA Office of Pesticide Programs (OPP) aquatic-life benchmarks with a level of concern for impacts to endangered and threatened species as the safe level for pesticides.

Unfortunately, no pesticide monitoring program exists throughout the migratory corridor, nor is there likely a program that will exist in the future that will be able to monitor all possible pesticides that may adversely impact adult salmonids during their migration to the Stanislaus River spawning area. Furthermore, the multitude of possible pesticide combinations, differing biochemical interactions of pesticides, and variations of direct and indirect effects precludes the possibility of quantifying the true impact of pesticides on salmonids in the Central Valley (e.g., EC25 of a surface water sample that included direct and indirect impacts of all contaminants).

So, the SEP group has relied on a pesticide prediction model (Hoogeweg et al. 2011) to estimate the current frequency of pesticide water quality objective or benchmark exceedances to categorize optimal, sub-optimal, and detrimental conditions for adult migration pesticide environmental objectives. That is, the categories are an evaluation of the risks that a species is exposed to pesticide concentrations that could cause harm in a river reach by month. The categories assume that, while zero occurrences of pesticides is preferred, such low levels of exposure may not be achievable considering the amount of urban and agricultural development in the Central Valley. Models, monitoring, toxicity bioassays, and other information will need to be updated, developed, conducted, and further gathered as needed in the future to determine if pesticide concentrations are adversely impacting salmonid migration to the Stanislaus River.

The SEP group used this approach (e.g., frequency of water quality criteria or benchmark exceedances) for all Chinook and steelhead life stages. For more information or rational for this approach, see Appendix B, Section 1.3.

7.2.1.4.3 Objectives

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 14 and 15. Pesticide concentrations necessary to protect Chinook salmon and steelhead migration are expected to be similar. Based on the described approach of pesticide environmental objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 16) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

Table 14
Central Valley Regional Water Quality Control Board Adopted and Proposed Water Quality Objectives for Current Use Pesticides

Pesticide	Acute (µg/L)	Chronic (µg/L)
Adopted Water Quality Objectives[1]		
Diazinon	0.16	0.1
Chlorpyriphos	0.025	0.015
Carbofuran	40	40
Simazine	4	4
Thiobencarb	1	1

Pentachlorophenol	5.3	4
Copper	5.7	4.1
Proposed Water Quality Objectives[2]		
Bifenthrin	0.00006	0.00001
Cyfluthrin	0.0002	0.00004
Lambda-Cyhalothrin	0.00003	0.00001
Cypermethrin	0.00004	0.00001
Esfenvalerate	0.0002	0.00003
Permethrin	0.006	0.001

Notes:
[1] CVRWQCB 2011
[2] Proposed water quality objectives for the Central Valley Pyrethroid Pesticides TMDL and Basin Plan Amendment (CVRWQCB 2015).
µg/L = microgram per liter

Table 15

USEPA Office of Pesticide Programs' Aquatic-Life Benchmarks for the 40 Pesticides that Pose the Greatest Risk in the Central Valley Region

Pesticide	Pesticide Type	Acute Benchmark (µg/L)	Endangered and Threatened Acute Benchmark (µg/L)	Chronic Benchmark (µg/L)	Source of Acute/ Chronic Value[1]
Abamectin	Insecticide	0.17	0.017	0.006	IA/IC
Bifenthrin	Insecticide	0.075	0.0075	0.0013	FA/IC
Bromacil	Herbicide	6.8	0.68	3000	AA/FC
Captan	Fungicide	13.1	1.31	16.5	FA/FC
Carbaryl	Insecticide	0.85	0.085	0.5	IA/IC
Chlorothalonil	Fungicide	1.8	0.18	0.6	IA/IC
Chlorpyrifos	Insecticide	0.05	0.005	0.04	IA/IC
Clomazone	Herbicide	167	16.7	350	AA/FC
Copper hydroxide	Fungicide	5.9	0.59	4.3	IA/IC
Copper sulphide	Insecticide/Algaecide	5.9	0.59	4.3	IA/IC
Cyfluthrin	Insecticide	0.0125	0.00125	0.007	IA/IC
Cyhalofop butyl	Herbicide	245	24.5	134	FA/FC
Cypermethrin	Insecticide	0.195	0.0195	0.069	FA/IC
Deltamethrin	Insecticide	0.055	0.0055	0.0041	IA/IC
Diazinon	Insecticide	0.11	0.011	0.17	IA/IC
Dimethoate	Insecticide	21.5	2.15	0.5	IA/IC

Diuron	Herbicide	2.4	0.24	26	AA/FC
Esfenvalerate	Insecticide	0.025	0.0025	0.017	IA/IC
Hexazinone	Herbicide	7	0.7	17000	AA/FC
Imidacloprid	Insecticide	35	3.5	1.05	IA/IC
Indoxacarb	Insecticide	12	1.2	3.6	FA/IC
Lambda cyhalothrin	Insecticide	0.0035	0.00035	0.002	IA/IC
Malathion	Insecticide	0.3	0.03	0.035	IA/IC
Mancozeb	Fungicide	47	4.7	N/A	AA/na
Maneb	Fungicide	13.4	1.34	N/A	AA/na
Methomyl	Insecticide	2.5	0.25	0.7	IA/IC
(s)-Metolachlor	Herbicide	8	0.8	30	AA/FC
Naled	Insecticide	25	2.5	0.045	AA/IC
Oxyfluorfen	Herbicide	0.29	0.029	1.3	AA/FC
Paraquat	Herbicide	0.396	0.0396	N/A	AA/na
Pendimethalin	Herbicide	5.2	0.52	6.3	AA/FC
Permethrin	Insecticide	0.01	0.001	0.0014	IA/IC
Propanil	Herbicide	16	1.6	9.1	AA/FC
Propargite	Insecticide	37	3.7	9	IA/IC
Pyraclostrobin	Fungicide	0.0015	0.00015	0.002	FA/FC
Simazine	Herbicide	36	3.6	960	AA/FC
Thiobencarb	Herbicide	17	1.7	1	AA/IC
Tralomethrin	Insecticide	0.055	0.0055	0.0041	IA/IC
Trifluralin	Herbicide	7.52	0.752	1.14	AA/FC
Ziram	Fungicide	9.7	0.97	39	FA/IC

Notes:
Source: USEPA Office of Pesticide Program (OPP)
Table modified from Hoogeweg et al. (2011).
Aquatic-life benchmarks are used by the USEPA-OPP for risk assessments in the registration of pesticides. To assess a pesticide not listed, the entire list of nearly 500 pesticide benchmarks can be acquired at: http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm
[1] Identifies which taxa was the most sensitive to the pesticide from available toxicity evaluations: FA = fish acute; IA = invertebrate acute; AA = Algae Acute; FC = fish chronic; IC = invertebrate chronic; na = not available
µg/L = microgram per liter

It is estimated salmon exposed to pesticides at a frequency 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control) (Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has similar impact on salmonid physiology and responses across all life stages, then exposures of pesticides greater than 30% (Bin 7-10, Table 16) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2-6, Table 16. See Appendix B, Section 1.3.3.1 for more information.

Table 16
Categories of Predicted Pesticide Aquatic-life Benchmark Exceedances

Bin Category	Condition	Range of the Frequency of Benchmark Exceedances		
1	Optimal	0	-	0.017
2	Sub-optimal	0.018	-	0.055
3		0.056	-	0.1
4		0.101	-	0.153
5		0.154	-	0.206
6		0.207	-	0.303
7	Detrimental	0.304	-	0.447
8		0.448	-	0.5
9		0.501	-	0.589
10		0.59	-	0.994

Note:
Frequencies were calculated from the total number of predicted exceedance days for each month from 2000 to 2009. Any day that had at least one pesticide that exceeded benchmarks was counted as an exceedance day (adapted from Hoogeweg et al. 2011).

7.2.2 Adult Holding

Spring-run Chinook salmon migrate upstream in the spring and require deep, cool, well-oxygenated water during the summer months while they rest and wait to spawn in the early fall. Adult steelhead and resident rainbow trout also require cool, well-oxygenated water during the summer months. During these resting periods, salmonids seek to minimize energy expenditures by avoiding high temperatures, high velocities, low-oxygen, and disturbances from predators or people.

Environmental objectives have been established for temperature, DO, water velocity, water depth, and contaminants. No objectives were developed for potential disturbance (people and predators) or distribution of holding habitat as these parameters seem unlikely to adversely impact oversummering adult salmonids in both the current and future states of the

Stanislaus River. The objectives and supporting rationale for each of these parameters is discussed below. A summary of environmental objectives is provided in Table A-2 (Appendix A).

7.2.2.1 Temperature

7.2.2.1.1 Rationale

Optimal water temperatures during the holding stage will allow the adult salmon to maintain a low metabolic rate. High temperatures during holding can increase their metabolic rate to a point where sufficient energy reserves will not be available for the rigors of digging redds, spawning, and nest guarding. Elevated pre-spawn mortality can occur if water temperatures are too high during the holding period (McCullogh 1999).

7.2.2.1.2 Approach

As described in detail in Section 1.1.2 of Appendix B, the SEP group relied primarily on USEPA (2003) guidance for temperature effects on Pacific salmon.

7.2.2.1.1 Objectives

USEPA (2003) reports reduced viability of gametes in holding adult salmonids at constant temperatures in excess of 13°C (55.4°F). While lethal temperatures (1 week constant exposure) range from 23°C to 26°C (73.4°F to 78.8°F), disease risk is high at 18°C to 20°C (64.4°F to 68°F).

Spring-run Chinook salmon in the Sacramento-San Joaquin River system spend the summer holding in large pools where summer temperatures are usually below 21°C to 25°C (69.8°F to 77°F) (Moyle et al. 1995). Sustained water temperatures above 27°C (80.6°F) are lethal to adult spring-run Chinook salmon (Moyle et al. 1995). Temperature objectives are included in Table 17.

Table 17

Temperature Objectives for Chinook Salmon and *O. mykiss* Adult Holding

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)

Upstream of Knights Ferry	April through September	Optimal	< 13°C (55.4°F) (Daily Average)
			< 14.5°C (58.1°F) (7DADM)
		Sub-optimal	13°C to 17°C (55.4°F to 62.6°F) (Daily Average)
			14.5°C to 18.5°C (58.1°F to 65.3°F) (7DADM)
		Detrimental	17°C to 18°C (62.6°F to 64.4°F) (Prolonged Exposure)
			18°C to 20°C (64.4°F to 68°F) (Average)

Note:
"<" = less than
°C°F = degrees Fahrenheit
7DADM = 7-day average of daily maximum temperature

7.2.2.1 Dissolved Oxygen

7.2.2.1.1 Rationale

Low levels of DO can result in adverse physiological effects on salmonids, up to and including death. Low DO levels, can be associated with high nutrient inputs, contaminated runoff from urban, industrial, or agricultural lands, or mass die-offs of algal species.

7.2.2.1.2 Approach

The SEP group used the same approach for holding habitat as that used for upstream migration as described in Section 7.2.1.2.2.

7.2.2.1.3 Objectives

The SEP group used the same objectives for holding habitat as that used for upstream migration as described in Section 7.2.1.2.3; however, these objectives are applied only to habitats upstream of Knights Ferry (see Table 18).

Table 18

DO Objectives for Chinook Salmon and *O. mykiss* Adult Holding

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Upstream of Knights Ferry	April through September	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

Notes:
">" = greater than
"<" = less than
mg/L = milligram per liter

7.2.2.2 Water Depth and Velocity

Water velocity experienced by adults during holding should be low enough so that little energy is expended. Spring-run Chinook salmon may hold for several months in a stream prior to spawning, so it is essential that they limit how much energy they use during this period. Water depth should be sufficient to provide cover and refuge from predators and human disturbance.

7.2.2.2.1 Rationale

Holding adult salmon seek to maximize energy reserves through occupying habitats with minimal nonzero velocities. Energy expended to hold position is energy not available for redd construction, spawning, and redd defense. Disturbance by predators or humans result in flight response of fish seeking to escape, using additional energy beyond that necessary to hold position.

7.2.2.2.2 Approach

The depth of the river should provide sufficient cover to hide from predators. Spring-run Chinook salmon hold in pools that are at least 1 m to 3 m (3.3 ft to 9.8 ft deep (Moyle et al. 1995), and usually greater than 2 m (6.6 ft) deep (Moyle 2002b).

Holding pools for adult spring-run Chinook salmon have been characterized as having moderate water velocities ranging from 0.15 m/s to 0.4 m/s (0.5 feet per second [ft/s] to 1.3 ft/s; DWR et al. 2000). According to Moyle (2002b), the adults prefer mean water column velocities of 0.15 m/s to 0.8 m/s (0.49 ft/s to 2.6 ft/s).

Holding pools usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day. Adult spring-run Chinook salmon also seek cover in smaller "pocket" water behind large rocks in fast water (Moyle et al. 1995).

7.2.2.2.3 Objectives

Targets for depth and velocity are presented in Table 19.

Table 19

Depth and Velocity Objectives for Chinook Salmon Adult Holding

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Upstream of Knights Ferry	April through September	Depth	≥ 1.5 m (4.9 ft)
		Velocity	< 0.37 m/s (1.2 ft/s)

Notes:
ft = foot
ft/s = foot per second
m = meter
m/s = meter per second

7.2.2.3 Contaminants

7.2.2.3.1 Rationale

Similar to adult upstream migration, poor water quality can continue to impact survival during holding. Studies in the Pacific Northwest have shown high pre-spawn mortality in Coho salmon due to urban contaminants such as in stormwater runoff (Feist et al. 2011; Scholz et al. 2011). In addition to pestcides, urban runoff contaminants often include metals, petroleum, and other compounds. However, unlike pesticides, there is no evidence that these other types of contaminants are currently causing an adverse impact in the holding reaches in the Stanislaus River. Consequently, no environmental objectives for these other contaminants are addressed in this report; however, urban runoff and other non-point discharges should occasionally be assessed in the future to confirm that there are no adverse impacts to salmonids.

7.2.2.3.2 Approach

Similar to adult upstream migration, the SEP group relied on adopted numeric water quality objectives for pesticides from the Sacramento and San Joaquin River Water Quality Control Plan, and proposed pesticide water quality objectives from developing pesticide control programs (CVRWQCB 2011, 2014, 2015) to determine pesticide levels that should provide no adverse impacts to adult holding. In addition, for pesticides that do not have state or federally promulgated objectives or criteria, the SEP group used the USEPA OPP aquatic-life benchmarks with a level of concern for impacts to endangered and threatened species as the safe level for pesticides.

Additionally, no regular pesticide monitoring program exists in the spawning reach, nor is there likely a program that will exist in the future that will be able to monitor all possible pesticides that may adversely impact adult salmonids during Stanislaus River holding. Consequently, the SEP group has relied on the Hoogeweg et al. (2011) pesticide prediction model to estimate the current frequency of pesticide water quality objective or benchmark exceedances to categorize optimal, sub-optimal, and detrimental conditions for adult holding pesticide environmental objectives (see Appendix B, Section 1.3 for further information). Models, monitoring, toxicity bioassays, and other information will need to be updated, developed, conducted, and further gathered as needed in the future to determine if pesticide concentrations are still adversely impacting salmonid holding in the Stanislaus River.

7.2.2.3.3 Objectives

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 14 and 15. Pesticide concentrations necessary to protect Chinook salmon and steelhead holding are expected to be similar. Based on the described approach of pesticide environmental objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 16) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

It is estimated salmon exposed to pesticides at a frequency 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control) (Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has similar impact on salmonid physiology and responses across all life stages, then exposures of pesticides greater than 30% (Bin 7-10, Table 16) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2-6, Table 16. See Appendix B, Section 1.3.3.1 for more information.

7.2.1 Spawning Habitat

Salmonids in the Pacific portion of North America have evolved a life-history that requires rivers and streams with relatively high gradients for reproduction and rearing. These waters tend to be cold, low in trace elements, low in nutrients, and high in oxygen. There also is a relatively high rate of movement within the sediment that sorts fine materials to lower elevations and larger pools more quickly than the larger sediments, resulting in sorting of sediment differentially in low and high velocity waters. The extensive building of large dams has changed the conditions within many of the Pacific rivers where salmonids were once very abundant (Ligon et al. 1995). The dams, while impeding the migration of adults to high elevation spawning areas, also tend to stop the flow of sediment and change water quality in ways that often reduce the use of those waters for salmonid spawning.

The water released downstream of reservoirs, often held in reservoirs for long periods of time, can have high levels of nutrients and trace elements that are toxic to various life stages of salmonids. Reservoirs are heat sinks, causing temperatures to rise and DO levels to drop. These changes will at various levels cause physiological stress on the salmonids using the river below the dam. Dams alter a river's hydrograph and sediment supply, reducing movement and availability of large sediment downstream of the dam and allowing fine sediment to settle into interstitial spaces among gravel and cobble. This altered geomorphology reduces suitability of any remaining spawning habitat downstream of a dam. Studies have often focused on changes in the structural aspects of spawning habitat downstream of dams (i.e., habitat quantity) rather than DO and other water quality parameters that contribute toward habitat quality. For example, Hanrahan et al. (2004) evaluated spawning habitat in a large drainage in the Columbia River system. The spawning habitat parameters they considered were a typical set of depth, velocity, substrate, and channel-bed slope.

Salmonids are somewhat unusual among stream fishes, in that they build nests by burying eggs below the surface of the substrate in what is referred to as a redd. Many non-salmonids do not build nests. They simply release eggs in a mass which are then fertilized in the water column and drift downstream (e.g., striped bass), or they extrude sticky eggs that then adhere to vegetation or substrate (e.g., sturgeon). Construction of redds requires flowing water within a particular velocity range and a gravel/cobble substrate with not too much sand and silt. Females fan the cobbles with their tail which lifts all the smaller cobbles, letting the current move them a short distance downstream to deposit in a mound referred to as the tail spill of the redd. Only a few large cobbles will be left in the pit that the female has dug. Into this pit the female deposits a portion of her eggs, which are then fertilized by a male's sperm. The female buries the fertilized eggs by digging another pit just upstream of the first and letting gravel and cobbles float downstream and fill in the pit. She repeats this process again and again until all of her eggs have been released. This results in a nest with multiple egg pockets, sometimes in excess of 5 or 6 pockets. The female defends the area from other nest builders for a short time and then dies or returns to the ocean. Months later the eggs will hatch, use up their yolk sac and emerge from this gravelly nest.

The structure of redds requires specific characteristics for sediment, water quality and placement of the redd within the river's geomorphology (Tonina and Buffington 2009). Free flowing rivers develop an alternating pool/riffle sequence structure that gives a non-uniform distribution of sediment within the river. The faster moving "riffles" have coarser sediment than the slower flowing pool areas. The result is that redds are generally built in the faster moving water that occurs in the coarse sediment areas, at the top and bottom of the riffles.

The distribution of sediment sizes, along with water velocity and depth, is an essential component to spawning habitat choice. Redd distribution in a river is patchy, reflecting the non-uniform distribution of sediment. Availability of coarse substrate (up to 10% of body length), swift water flow, and the structure of a redd are important to maintaining water quality in the nest for egg incubation (Tonina and Buffington 2009; Merz et al. 2013). That in combination with placing a redd at the top or bottom of the riffles increases the permeation of water through the redd, thus improving water quality and increasing survival of eggs over the 1.5 to 3 months of incubation. Stressful conditions can negatively affect spawning success. Factors such as high water temperatures, high spawner densities, and presence of pathogens can contribute to prespawn mortality or high rates of egg retention in females (Quinn et al. 2007).

Parameters considered important in this review of spawning habitat are quantity and quality of available habitat, temperature, DO, pesticides, trace element contaminants, and water flow (depth and velocity). Optimal levels of some of these parameters vary between species (gravel particle size distributiondepth, velocity, and temperature), while the criteria for DO, pesticides, and trace element contaminants are the same for both species. Most of the variation between species is a result of differences in body size, which has often been identified as the primary factor affecting variance in salmonid spawning habitat (Zeug et al. 2013; Kondolf 2000). Body size determines the preferred particle size distribution that makes up quality spawning habitat.

7.2.1.1 Temperature

7.2.1.1.1 Rationale

The background and development of these temperature objectives are discussed in Appendix B, Section 1.1. Adult spawning Chinook salmon and steelhead temperature needs are generally similar to their eggs. Considerations specific to spawning habitat include temperature triggers for spawning and potential thermal stress that could lead to high rates of prespawn mortaility and egg retention. In general, the temperature criteria for eggs are protective of spawning as well as the subsequent egg incubation phase.

7.2.1.1.2 Approach

Salmonid eggs and larvae require cold water to successfully complete spawning and incubation. With the construction of impassable dams, Chinook salmon spawning in the San Joaquin Valley became dependent on cold-water storage in reservoirs to provide sufficient cold-water storage to protect their incubating eggs. The accessible supply of cold-water storage limits successful spawning habitat for Chinook salmon populations in the Central Valley in general, and the San Joaquin River basin in particular.

USEPA (2003) found that constant temperatures between 4°C to 12°C (39.2°F to 53.6°F) result in good egg survival and that a narrower range (6°C to 10°C [42.8°F to 50°F]) is optimal; a 7DADM of less than 13°C (55.4°F) is recommended (Table 20). In a review, the USFWS (1999 cited by Myrick and Cech 2004) concluded that temperature-related egg mortality in Chinook salmon increased at temperatures above 13.3°C (55.9°F) and this is the limit applied in most regulatory arenas (e.g., NMFS 2009b; SWRCB Order 90-05). A review of research on different populations of Chinook salmon from within and outside of the Central Valley indicated that temperatures between 6°C and 12°C (42.8°F to 53.6°F) were optimal for Central Valley Chinook salmon (Myrick and Cech 2004).

As with Chinook salmon, *O. mykiss* eggs and larvae require cold water to successfully complete incubation. With the construction of impassable dams, *O. mykiss* eggs incubating in the San Joaquin Valley became dependent on cold-water storage in reservoirs. The accessible supply of cold-water storage limits successful spawning habitat for *O. mykiss* populations in the southern Central Valley. There is a serious lack of peer-reviewed studies on the temperature tolerances of Central Valley anadromous *O. mykiss* eggs, and additional study of temperature impacts on this species' eggs is needed (Myrick and Cech 2004). Optimal incubation temperatures for steelhead occur in a narrower range than those for Chinook salmon. Indeed, Myrick and Cech (2004) warned against managing water temperatures for the upper end of the Chinook salmon thermal tolerance range in waterways and during periods when steelhead are also incubating because incubating steelhead cannot tolerate such high temperatures. Richter and Kolmes (2005) concluded that egg mortality increased as incubation temperatures exceeded 10°C (50°F) and substantial mortality may occur when temperatures exceed 13.5°C to 14.5°C (56.3°F to 58.1°F). Based on experience at hatcheries in the Central Valley, optimal incubation temperatures appear to be in the 7°C to 10°C (44.6°F to 50°F) range (Myrick and Cech 2004). California's steelhead management plan (McEwan and Jackson 1996) suggests a slightly higher temperature range (from 9°C to 11°C [48.2°F to 51.8°F]).

7.2.1.1.3 Objectives

Temperature objectives for Chinook salmon and steelhead spawning are provided in Tables 20 and 21.

Table 20

Temperature Objectives for Chinook Salmon Spawning

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Spawning Gravel (Generally upstream of RM 20)	**Fall-run:** Late October to March **Spring-run:** Late August to March	Optimal	6 °C to 12°C (42.8°F to 53.6°F) (Daily Average)
			< 12.5°C to 13°C (54.5°F to 55.4°F) (7 DADM)
		Sub-optimal	4°C to 6°C (39.2°F to 42.8°F) (Daily Average))
			12°C to 13.3°C (53.6°F to 55.9°F) (Daily Average)

			12.5°C to 13.8°C (54.5°F to 56.8°F) (7DADM)
		Detrimental	> 13.3°C (55.9°F) (Daily Average)
			> 13.8°C (56.8°F) (7DADM)

Notes:
“>” = greater than
“<” = less than
°C°F = degrees Fahrenheit
7DADM = 7-day average of daily maximum temperature

Table 21
Temperature Objectives for Steelhead Spawning

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Spawning Gravel (Generally upstream of RM 20)	December to June	Optimal	7°C to 10°C (44.6°F to 50°F) (Daily Average)
			10.5°C (50.9°F) (7DADM)
		Sub-optimal	4°C to 7°C (39.2°F to 44.6°F) (Daily Average)
			10°C to 13.5°C (50°F to 56.3°F (Daily Average)
			10.5°C to 14.0°C (50.9°F to 57.2°F (7DADM)
		Detrimental	> 13.5°C (56.3°F) (Daily Average)
			> 14.0°C (57.2°F) (7DADM)

Note:
“>” = greater than
°C°F = degrees Fahrenheit
7DADM = 7-day average of daily maximum temperature

7.2.1.2 Dissolved Oxygen

7.2.1.2.1 Rationale

The background and development of these DO objectives are discussed in Appendix B, Section 1.2. Adult spawning Chinook salmon and steelhead DO needs are generally similar to their eggs. However the eggs are more sensitive to oxygen minima and since the result of spawning is the production of eggs, the dissolved criteria for eggs becomes the limiting factor for spawning. Therefore the spawning DO objective below is the same as the DO objective identified for egg incubation.

7.2.1.2.2 Approach

The summaries of egg incubation mortality through hatching and incubation growth rates in Section 7.2.4.1.2 provide rationale for the DO objectives identified below.

7.2.1.2.3 Objectives

DO objectives for Chinook salmon and steelhead spawning are provided in Table 22.

Table 22
DO Objectives for Chinook Salmon and Steelhead Spawning

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Gravel (Measurement must occur in gravel, not water column)	**Fall-run:** Late October to March **Spring-run:** Late August to March **Steelhead:** December to June	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	<6 mg/L (Daily Minimum)

Notes:
">" = greater than
"<" = less than
mg/L = milligram per liter

7.2.1.3 Contaminants

7.2.1.3.1 Rationale

The background and development of these contaminant objectives are discussed in Appendix B, Section 1.3. Adult spawning Chinook salmon and steelhead likely have some differences in sensitivities to the various contaminants; however, the SEP group does not believe that the studies support separate contaminant environmental objectives for each of the species. Therefore, the contaminant objectives will be applicable to all species during their period of spawning. In addition, mercury and selenium bioaccumulation in the ocean are likely low and returning adults cease to eat during their spawning period, so there are low risks to adult salmonid spawning from mercury and selenium. Therefore, pesticides are the only contaminants that have perceived direct impacts on adult spawning in the Stanislaus River, and only pesticide objectives necessarily need to be discussed for this life stage.

Pesticides can have both lethal and sub-lethal impacts to salmonid spawners. Pre-spawn mortality of adult salmonids from pesticide exposures is discussed in the migration and contaminant sections, so there is some evidence that salmonids will die prior to spawning. However, the studies of the causes of prespawn mortality were not able to specify whether mortality occurred during the acts of migration, holding, or spawning (Scholz et al. 2011).

Spawning is at greater risk from the sub-lethal impacts of pestcides than spanwer mortality. Most pesticides, in addition to other chemical contaminants like metals, have been found to disrupt fish olfaction (Hansen et al. 1999; Moore and Waring 2001; Scholz et al. 2000). Disruption in olfaction has been linked to the elimination of fish behaviors important for reproduction (Potter and Dare 2003; Scott and Sloman 2004). For example, the pyrethroid insecticide cypermethrin inhibited male Atlantic salmon from detecting and responding to the reproduction priming pheromone prostaglandin, which is released by ovulating females (Moore and Waring 2001). The males exposed to cypermethrin did not respond to prostaglandin with the expected increased levels of plasma sex steroids and expressible milt. The disruption of spawning synchronization would likely result in an increase in the number of unfertilized eggs in the river (NMFS 2009c).

Pesticide exposures have been found to decrease the number of viable fertilized eggs. For example, the previously mentioned Moore and Waring (2001) found that salmon egg and milt exposed to cypermethrin had a greater number of unfertilized eggs. In another laboratory study, adult zebrafish exposed to deltamethrin at low doses for 3 months showed reduce fecundity in females, and the number of unhatched fertilized eggs increased when compared the to control (Sharma and Ansari 2010). Furthermore, even short adult exposures to pesticides have been shown to impair fish reproduction. For instance, Brander and others (2014) observed that 7-day exposures to bifenthrin caused significant differential expression of genes related to reproduction and immune function at sub-lethal concentrations to *Menidia beryllina* (inland silversides). As well, Brander and others (2014) reported a statistically significant 30% reduction in fertilized eggs from the adult *Menidia beryllina*, and their population dynamic modeling predicted that these reductions in reproductive success would cause a significant decline in fish population over time.

7.2.1.3.2 Approach

Similar to adult upstream migration, the SEP group relied on adopted numeric water quality objectives for pesticides from the Sacramento and San Joaquin River Water Quality Control

Plan, and proposed pesticide water quality objectives from developing pesticide control programs (CVRWQCB 2011, 2014, 2015) to determine pesticide levels that should provide no adverse impacts to spawning. In addition, for pesticides that do not have state or federally promulgated objectives or criteria, the SEP group used the USEPA OPP aquatic-life benchmarks with a level of concern for impacts to endangered and threatened species as the safe level for pesticides.

Additionally, no regular pesticide monitoring program exists in the spawning reach, nor is there likely a program that will exist in the future that will be able to monitor all possible pesticides that may adversely impact adult salmonids during Stanislaus River spawning. Consequently, the SEP group has relied on the Hoogeweg et al. (2011) pesticide prediction model to estimate the current frequency of pesticide water quality objective or benchmark exceedances to categorize optimal, sub-optimal, and detrimental conditions for spawning pesticide environmental objectives (see Appendix B, Section 1.3 for further information). Models, monitoring, toxicity bioassays, and other information will need to be updated, developed, conducted, and further gathered as needed in the future to determine if pesticide concentrations are still adversely impacting salmonid spawning in the Stanislaus River.

7.2.1.3.3 Objectives

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 14 and 15. Pesticide concentrations necessary to protect Chinook salmon and steelhead spawning are expected to be similar. Based on the described approach of pesticide environmental objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 16) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

It is estimated salmon exposed to pesticides at a frequency 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control) (Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has similar impact on salmonid physiology and responses across all life stages, then exposures of pesticides greater than 30% (Bin 7-10, Table 16) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2-6, Table 16. See Appendix B, Section 1.3.3.1 for more information.

7.2.1.4 Depth and Velocity

7.2.1.4.1 Rationale

Two of the most obvious habitat components that salmonids can detect and choose when picking redd sites are depth and velocity of the water. These two components are considered part of the core component of spawning habitat for salmon and steelhead (Hanrahan et al. 2004) and they have been used as part of the definition of salmonid spawning habitat for more than fifty years (Bovee 1978; Thompson 1972; and Wickett 1958). These components have become important to a form of river habitat evaluation called IFIM/PHABSIM (for early work on Stanislaus River see Aceituno 1993). Recent work has been performed on the Stanislaus River modeling depth and velocity throughout the river (USBOR 2007).

7.2.1.4.2 Approach

The tool used to describe depth and velocity is referred to as habitat suitability index (HSI) or habitat suitability criteria (HSC). Both refer to a curve that represents the relative usefulness of particular depth (y-axis) or velocity (x-axis) for spawning by ascribing an index value of 0 to 1 (0 = useless, 1= most preferred). These charts are developed from measurements of actual redd locations (see Gard 2006 for example), which are then used to produce a probability curve with the x-axis representing the increments of the measured component that were used (such as depth) and the y-axis shows the percent of redds that fell in that increment. If a large sample of redd measurements are made, the probability curves for the depths and velocities can become the HSI by making the highest probability equal to 1 and adjusting all other values equally (essentially divide by maximum probability. The following criteria are based on the assumptions that HSI greater than 0.6 is optimum, all other values of habitat used are suboptimum (0< HSI ≤6), and all values outside of the range used by salmonids are considered detrimental (which is essentially habitat that cannot be used for spawning). In this context "non-habitat" is a better term than "detrimental."

Chinook salmon have been observed spawning in a broad range of water depths (0.15 m to 4.6 m [0.5 ft to 15 ft]), although the preferred range is approximately 0.61 m (2 ft) deep for fall-run (Gard 2006). Using these data, optimum habitat is 0.3 m to 0.76 m (1 ft to 2.5 ft) in depth, with suboptimal ranging from 0.15 m to 0.3 m (0.5 ft to 1 ft) on the shallow end and 0.76 m to nearly 4.6 m (2.5 ft to nearly 15 ft) in deep water. However, very few observations of spawning were made in water greater than 3.05 m (10 ft) deep. Gard (2006) found that optimal water velocity ranged from 0.3 m/s to 1.2 m/s (1 ft/s to 4 ft/s). Outside of that range, velocities down to 0.12 m/s (0.4 ft/s) and up to 1.5 m/s (5 ft/s) could support some spawning, but should be considered suboptimal. Gard (2006) had few observations of spawning at velocities greater than 1.2 m/s (4 ft/s); thus 1.2 m/s (4 ft/s) should be considered the upper limit of spawning.

For steelhead, depth and velocity criteria are slightly smaller due to the smaller average size of the adult fish. Hannon (2015) has done an extensive review of steelhead literature. Depths of 0.36 m (1.17 ft) (average), 0.15 m to 0.61 m (0.5 ft to 2 ft) (range) that were developed by Bovee (1978: cited in McEwan and Jackson 1996, and AFRP working paper) are largely supported by Hannon's (2015) review. As with Chinook, steelhead are more sensitive to water velocity than depth when selecting redd locations. Hannon observed optimal velocities during spawning of 0.3 m/s to 1.1 m/s (1 ft/s to 3.6 ft/s), which also support established recommendations for the Central Valley. Bovee (1978 as cited in McEwan and Jackson 1996 and the AFRP working paper) found 0.61 m/s (2.0 ft/s) was the preferred velocity, and Reynolds et al. (1993, as cited in the AFRP working paper) found 0.46 m/s (1.5 ft/s) was preferred. Suboptimal velocities are identified as a very small range at the lower end of the velocities; flows outside that overall range are considered to be detrimental or "non-habitat."

7.2.1.4.3 Objectives

Depth and velocity objectives for Chinook salmon and steelhead spawning (eggs/larvae) are provided in Tables 23 and 24.

Table 23
Depth and Velocity Objectives for Chinook salmon Spawning

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (metric)
Upstream of RM 20	**Fall-run:** Late October to December **Spring-run**: Late August to October	Optimal	Depth: 0.3 m to 0.76 m (1 ft to 2.5 ft)
			Velocity: 0.3 m/s to 1.2 m/s (1 ft/s to 4 ft/s)
		Sub-optimal	Depth: 0.15 m to 0.3 m (0.5 ft to 1 ft) and 0.76 m to 3.05 m (2.5 ft to 10 ft)
			Velocity: 0.12 m/s to 0.3 m/s (0.4 ft/s to 1 ft/s)
		Detrimental	Depth: < 0.15 m (< 0.5 ft) or > 3.05 m (> 10 ft)
			Velocity: < 0.12 m/s (< 0.4 ft/s) or > 1.5 m/s (> 5 ft/s)

Notes:
"<" = less than
">" = greater than
ft = foot
ft/s = foot per second
m = meter
m/s = meter per second

Table 24

Depth and Velocity Objectives for Steelhead Spawning

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (metric)
Upstream of RM 20	December to April	Optimal	Depth: 0.15 m to 0.61 m (0.5 ft to 2 ft)
			Velocity: 0.5 m/s to 1.1 m/s (1.6 ft/s to 3.6 ft/s)
		Sub-optimal	Depth: 0.08 m to 0.15 m (0.26 ft to 0.5 ft) and 0.61 m to 1 m (2 ft to 3.3 ft)
			Velocity: 0.32 m/s to 0.4 m/s (1.1 ft/s to 1.3 ft/s)
		Detrimental	Depth: < 0.08 m (0.26 ft) or > 1 m (> 3.3 ft)
			Velocity: < 0.3 m/s (< 0.98 ft/s) or > 1.2 m/s (> 4 ft/s)

Notes:
"<" = less than
">" = greater than
ft = foot
ft/s = foot per second
m = meter
m/s = meter per second

7.2.1.5 Sediment Size Distribution

7.2.1.5.1 Rationale

Sediment size is an important consideration in the construction of redds. Most simply, the female fish must be able to move most of the coarse sediments at the chosen site with a fanning of her tail. There is a long history and a large number of evaluations of coarse sediment available for review (Reiser and Bjornn 1979; Barnhart and Parsons 1986; Healey 1991; and Williams 2008). These indicate a large variation in the extent sizes of gravel considered appropriate by salmon for spawning. Much of this variation is a result of varying size of the females.

7.2.1.5.2 Approach

Coarse gravel is essential for holding the eggs in the redd without blocking too much of the water flow. Kondolf and Wolman (1993) give an extensive review of studies to identify characteristics of gravel that are chosen by salmonids (also see Kondolf 2000). They looked at a variety of gravel size metrics and species. For the purposes of this report, the D_{50} metric will be used to determine appropriate sizes from the two reports mentioned above; however, the distribution of particle sizes is ultimately the most important factor in habitat suitability (Table 26). The two species will be differentiated based on size. The largest size of a female for steelhead will be assumed to be 600 mm (23.6 in), and the largest assumed size for Chinook will be assumed to be 1,000 mm (39.4 in).

Based on Kondolf and Wolman (1993) and Kondolf (2000), average values for D_{50} were abstracted in two ways. Kondolf and Wolman (1993) had box-and-whisker plots that summarized the distribution of gravel sizes used for spawning by salmonids from a large number of studies for each species. Using these, the optimal level for each species was defined as the range from lower 25% to the upper 75% of the distribution of gravel sizes or the interquartile range (IQR). For Chinook, this gives a range from 48 mm to 22 mm (1.89 in to 0.87 in). For steelhead, the range is from 25 mm to 15 mm (0.98 in to 0.59 in). The full range of the distribution of gravel sizes used for spawning by salmonids was then used to define the suboptimal ranges—Chinook run from 80 mm to 10 mm (3.15 in to 0.39 in) and steelhead from 48 mm to 10 mm (1.89 in to 0.39 in).

The second method for determining the optimum and suboptimum values was using the size of female versus D_{50} of sediment graph that was abstracted from studies. This graphic was used from Kondolf (2000) as it was easier to review, although the graphic was also included in Kondolf and Wolman (1993). This graphic required the definition of maximum size of female by species, which was done above. The optimum range was defined as the values between the best fit line (average for all values) and half way to the upper envelope curve limit line. The full range is from the lowest value recorded to the upper limit line. Suboptimal values are all the values in the full range that are outside the optimum range. Using this method the steelhead optimum range was 35 mm to 20 mm (1.38 in to 0.79 in) (full range 55 mm to 5 mm [2.2 in to 0.2 in]), and the Chinook optimum range is 60 mm to 30 mm (2.36 in to 1.18 in) (full range 85 mm to 25 mm [3.35 in to 0.98 in]).

Averaging these two assessments (using data from many studies) gives a steelhead optimum range of 30 mm to 15 mm (1.18 in to 0.59 in) and a full useable range of 50 mm to 10 mm (1.97 in to 0.39 in). The Chinook optimum with this same averaging technique results in an optimum range from 55 mm to 25 mm (2.2 in to 0.98 in) and a full useable range of 80 mm to 10 mm (3.15 in to 0.39 in). Since the 5 mm (0.2 in) sediment is in the range of sediment that is considered fine sediment and detrimental at least to Chinook, the decision was made to limit coarse sediment to the 10 mm size (0.39 in) (essentially, 0.5 in). Detrimental values are anything outside the full range of observed spawning, which is detrimental in the sense that it is by definition not spawning habitat. The detrimental range includes coarse sediment that is too large for a female to move and fine sediment that plugs interstitial spaces between gravel and small cobble, thus reducing water flow.

7.2.1.5.3 Objectives

Coarse sediment objectives for Chinook salmon and steelhead spawning are provided in Tables 25, 26, and 27.

Table 25
Sediment Size Distribution Objectives for Chinook salmon Spawning

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Upstream of RM 20	Fall-run: Late October to December **Spring-run:** Late August to October	Optimal	D_{50} 55 mm – 25 mm (2.2 in to 0.98 in)
		Sub-optimal	D_{50} 80 mm to 56 mm (3.15 in to 2.2 in) and 24 mm to 10 mm (0. 94 in to 0.39 in)
		Detrimental	Not spawning habitat D_{50} < 9 mm (0.35 in) or > 81 mm (3.19 in)

Notes:
"<" = less than
">" = greater than
in = inch
mm = millimeter

Table 26

AFRP Recommendations for Sediment Particle Size Distribution for Spawning Habitat

Particle Size (inches)	Percent passing	Percent retained
4 or 5	95% to 100%	0% to 5%
2	75% to 85%	15% to 30%
1	40% to 50%	50% to 60%
3/4	25% to 35%	60% to 75%
1/2	10% to 20%	85% to 90%
1/4	0% to 5%	95% to 100%

Table 27

Sediment Size Distribution Objectives for Steelhead Spawning

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Upstream of RM 20	December to April	Optimal	D_{50} 30 mm to 15 mm (1.18 in to 0.59 in)
		Sub-optimal	D_{50} 50 mm to 30 mm (1.97 in to 1.18 in) and D_{50} 15 mm to 10 mm (0.59 in to 0.39 in)
		Detrimental	Not spawning habitat $D_{50} < 9$ mm (0.35 in) or $D_{50} > 51$ mm (2 in)

Notes:
"<" = less than
">" = greater than

7.2.1.6 Sediment Quantity and Distribution Objectives

A number of objectives associated with spawning habitat do not fit into an optimal/suboptimal framework. They will be dealt with in this subsection as a group and will not have a table of values. The first of these objectives addresses the question of how much habitat Chinook and steelhead need for spawning. Other subsections described the quality of the habitat needed but did not address the quantity of that habitat. A spreadsheet model was developed and used to estimate the number of female Chinook that would be needed to reach the population goal that has been identified for the Stanislaus.

Fall-run Chinook were identified as needing 14.74 (minimum) acres of suitable spawning habitat for the abundance target for the Stanislaus, particularly at the tail of holding pools. The calculations used are based on average redd size for Chinook of 10 m^2 (107.6 ft^2) and for steelhead of 5 m^2 (53.8 ft^2) (Hannon 2015; Orcut et al. 1968 for steelhead is close to Hannon's estimate). Assuming fall-run on the Stanislaus have similar redd sizes, then an abundance target of 12,500 (60% female, 7,500 females) would need a minimum of 18.5 acres of spawning habitat (10 m^2 [107.6 ft^2]/female * 7,500 females = 75,000 m^2 [807,293 ft^2] = 7.5 hectares [18.5 acres]). There is no evidence that spring-run would have different redd sizes than fall-run on the Stanislaus, and the spring-run abundance target and ratio of males to females are the same as fall-run. Therefore, the amount of spawning habitat needed for spring-run would be the same as fall-run at 18.5 acres.

The *O. mykiss* target was identified as 2.7 acres. The steelhead redd size used to arrive at this value is 5.43 m^2 (58.4 ft^2) (from Orcutt et al. 1968) and a territory buffer of 50% (just over 2.5 m^2 [26.9 ft^2]), resulting in a value of 8 m^2 (86.1 ft^2)/female. The population size would be an average of 600 female spawners. The calculation for steelhead spawning habitat is 600 females * 8 m^2 [86.1 ft^2] per female = 4,800 m^2 = 1.19 acres). In addition, spawning habitat is needed for resident rainbow trout to meet the *O. mykiss* objective. For resident rainbows, Hannon's (2015) measurement of 1.35 m^2 (14.5 ft^2) per redd was used, plus a territory buffer of 50%, for a total of approximately 2 m^2 (21.5 ft^2) per redd. The target population size for resident rainbows is 3,000 adult females. Thus, the calculation is 3,000 females * 2 m^2 (21.5 ft^2) per female = 6,000 m^2 = 1.48 acres. Thus, the total amount of spawning habitat needed for *O. mykiss* is 1.2 acres for steelhead plus 1.5 acres for resident rainbow trout, for a total of 2.7 acres.

Additional considerations for spawning habitat for Chinook and steelhead include the need for cover and feeding areas adjacent to spawning areas, including holding pools, undercut banks, overhanging vegetation, large wood, and boulders. Spawning habitat should be increased in locations in the river that address the specific needs of spring-run and steelhead, in addition to fall-run. One possible action would be to provide additional spawning habitat in the canyon downstream of Goodwin Dam where temperatures are generally low and fall-run are less likely to spawn.

7.2.2 Egg Incubation

The egg incubation life stage takes place in the gravel, beginning when the female salmon or steelhead deposits her eggs in a redd and ending when fry swim up out of the river bottom. The entire life stage lasts roughly 3 to 5 months, depending on egg and alevins developmental rates, which are determined by water temperature. Egg incubation in the Stanislaus River generally occurs from late October through March for fall-run Chinook salmon and from December through June for steelhead. For spring-run Chinook salmon in the Sacramento River basin, egg incubation generally occurs from September through March; it is assumed that that timeframe also would apply for spring-run Chinook salmon in the Stanislaus River should a population become re-established there.

Salmon and steelhead eggs incubating in the gravel are vulnerable to low DO, warm water temperatures, poor water quality, physical disturbance, and low flows that result in redd dewatering or insufficient water velocity to maintain water quality. The eggs require clean, cold, well-oxygenated water. Without enough swiftly moving water moving through the redd to sweep out fine sediment and metabolic waste, the eggs cannot receive sufficient clean, oxygenated water for proper development and mortality often results. In order to evaluate whether or not the Stanislaus River is providing conditions during egg incubation that will support attainment of the biological objectives, environmental objectives for DO, water quality (pesticides and other contaminants), water temperature, and fine sediment were established. The objectives and supporting rationale for each of these parameters is discussed below. The objectives for water temperature are species-specific and are presented as such, whereas the objectives for DO and water quality do not vary by species, so one set of objectives is presented for all three species. A summary of environmental objectives is provided in Table A-4.

7.2.2.1 Dissolved Oxygen

7.2.2.1.1 Rationale

Adequate concentrations of DO in water are critical for salmon and steelhead survival. In freshwater streams, hypoxia can impact the growth and development of salmon and steelhead eggs, alevins, and fry as well as the swimming, feeding, and reproductive ability of juveniles and adults. If salmonids are exposed to hypoxic conditions for too long, mortality can result (Carter 2005). Without achieving optimal or some combination of optimal and sub-optimal environmental objectives for DO described below, the biological objectives for Chinook salmon and steelhead productivity most certainly will not be met.

7.2.2.1.2 Approach

The SEP group relied on DO criteria established by the USEPA (1986) and the CVRWQCB (2011), as well as relevant technical literature (e.g., WDOE 2002), to identify DO objectives that are optimal (no negative effects), sub-optimal (observably negative, though not significantly harmful), and detrimental (clearly harmful) ranges for various salmonid life stages and/or transitions. The approach the SEP group used to translate available information on impairment levels into optimal, sub-optimal, and detrimental objectives is shown in Table 12.

The criteria established by the USEPA and CVRWQCB covered cold water species in one category; separate criteria for Chinook salmon and steelhead were not provided. This blanket approach of protecting salmon and steelhead with one set of DO criteria is supported by the available literature, and as such, the SEP group followed that approach.

The following summaries of egg incubation mortality through hatching and incubation growth rates provide rationale for the DO objectives identified in Table 28.

Egg Incubation Mortality through Hatching (from WDOE 2002)

At favorable incubation temperatures, mortality rates should be expected to remain less than 1% at a concentration of 9 mg/L or greater, less than 2% at a concentration of 7 mg/L, and between 2% and 6% at a concentration of 6 mg/L. While mean oxygen concentrations over the development period below 6 mg/L are sometimes associated with significant increases in mortality rates, the overall pattern is for mortality rates and the occurrence of abnormalities to remain low (less than 7%) at concentrations above 4 mg/L. Survival rates at oxygen concentrations below 4 mg/L are highly variable. While mortality rates were low (4% to 7%) in some studies, they ranged from 25% to 100% in others. All tests at concentrations below 1.7 mg/L resulted in 100% mortality. While mortality rates related to low oxygen concentrations remain relatively minor at favorable incubation temperatures (averages below 11°C [51.8°F]), they increase rather substantially at temperatures that are warmer than ideal. In warmer waters (13.4°C [56.1°F]), even a decrease from 11 mg/L to 10 mg/L would be associated with causing a 4% reduction in survival through hatching. A decrease to 7 mg/L would be associated with a 19% reduction in survival. An important point to recognize is that in the laboratory studies upon which the developing alevin did not need to push their way up through gravel substrate as would wild fish. The studies above focused on survival through hatching and did not consider this rather substantial final act for emerging through the redds. Optimal fitness will likely be required for optimal emergence in the natural environment, and the metabolic requirements to emerge would be expected to be substantial. Thus, higher oxygen levels may be needed to fully protect emergence than to just fully support hatching alone.

Incubation Growth Rates (from WDOE 2002)

Any decrease in the mean oxygen concentration during the incubation period appears to directly reduce the size of newly hatched salmonids. At favorable incubation temperatures, the level of this size reduction, however, should remain slight (2%) at mean oxygen concentrations of 10.5 mg/L or more and still remain below 5% at concentrations of 10 mg/L or more. At 9 mg/L, the size of hatched fry would be reduced approximately 8%. Mean concentrations of 7 mg/L and 6 mg/L would be expected to cause 18% and 25% reductions in size.

7.2.2.1.3 Objectives

DO objectives for egg incubation for Chinook salmon and steelhead are presented in Table 28.

Table 28
DO Objectives for Chinook Salmon and Steelhead Egg Incubation

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Gravel (Measurement must occur in gravel, not water column)	**Fall-run:** Late October to March **Spring-run:** Late August to March **Steelhead:** December to June	Optimal	> 8 mg/L (Daily Minimum)

		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

Notes:
">" = greater than
"<" = less than
mg/L = milligram per liter

7.2.2.2 Contaminants

7.2.2.2.1 Rationale

Poor water quality has a high potential of impacting the survival and recovery of salmonids. Pesticides, mercury, and selenium have the ability to impact all life stages of salmonids, including the egg incubation stage. Exposure to these contaminants can occur through transfer from the maternal parent or through direct contact in the water or gravel. For example, as explained further in Appendix B, Section 1.3.1, mercury and selenium exposure to eggs and early-life stages (ELS) will be from maternal transfer because eggs are fairly resistant to these contaminants, and toxicity to mercury and selenium typically occurs from long-term bioaccumulation. Effects to ELS fish from mercury and selenium include developmental deformities, reduced hatch, increased pre-swimup mortality, and behavior abnormalities.

Contrary to mercury and selenium, current use pesticides are not typically bioaccumulative, and toxicity to eggs and ELS salmonids can occur from river exposures. In addition to a reduction in fertilized eggs discussed earlier, further evidence supports that pesticides impact salmonid egg to fry development. For example, Du Gas (2008) observed that exposures to herbicides atrazine and chlorothalonil in gravel-bed flume incubators resulted in reduce survival to hatch, increased finfold deformities, reduce condition factors at emergence, and premature emergence in Sockeye salmon. Furthermore, another laboratory study that exposed Chinook eyed eggs and alevins to dinosed (herbicide), diazinon (organophosphate insecticide), and esfenvalerate (pyrethroid insecticide) resulted in abnormal swimming behavior, myoskeletal abnormailites, and metabolic disruptions, as well as mortality at high concentrations (Viant et al. 2006). Alevins were much more sensitive to pesticide exposures than the eyed eggs, which emphasizes the importance of pesticide exposures to the critical life stages of alevin development and emergence (Finn 2007; Du Gas 2008; Viant et al. 2006).

7.2.2.2.2 Approach

Similar to the previous life stages, the SEP group relied on adopted numeric water quality objectives for pesticides from the Sacramento and San Joaquin River Water Quality Control Plan, and proposed pesticide water quality objectives from developing pesticide control programs (CVRWQCB 2011, 2014, 2015) to determine pesticide levels that should provide no adverse impacts to egg incubation. In addition, for pesticides that do not have state or federally promulgated objectives or criteria, the SEP group used the USEPA OPP aquatic-life benchmarks with a level of concern for impacts to endangered and threatened species as the safe level for pesticides.

Additionally, no regular pesticide monitoring program exists in the spawning reach, nor is there likely a program that will exist in the future that will be able to monitor all possible pesticides that may adversely impact egg incubation in the Stanislaus River. Consequently, the SEP group has relied on the Hoogeweg et al. (2011) pesticide prediction model to estimate the current frequency of pesticide water quality objective or benchmark exceedances to categorize optimal, sub-optimal, and detrimental conditions for egg incubation pesticide environmental objectives (see Appendix B, Section 1.3 for further information). Models, monitoring, toxicity bioassays, and other information will need to be updated, developed, conducted, and further gathered as needed in the future to determine if pesticide concentrations are still adversely impacting salmonid egg incubation in the Stanislaus River.

The SEP group relied on the draft USEPA National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life (2014) for the environmental objectives to protect salmonid species in the Stanislaus River against adverse effects. The criteria have yet to be promulgated; however, the criteria are consistent with the relevant technical literature on selenium toxicology. The environmental objective should be reevaluated once the USEPA selenium cirteria are finalized. No criteria have been developed for the protection of fish from mercury impacts. However, in recent literature, researchers have developed fish tissue mercury concentration benchmarks that are estimated to be protective of adult and ELS fish (see Appendix B, Section 1.3.2.2). The SEP group relied in these benchmark concentrations as the level that would be fully protective of salmonids during their egg incubation stage.

Furthermore, selenium and mercury objectives are presented as the maximum contaminant concentration to be found in eggs and ELS fish tissue, as well as the maximum tissue concentration allowable in maternal salmonids to prevent the toxicological transfer of mercury and selenium because egg and ELS fish exposure to mercury and selenium are through maternal transfer (Presser and Luoma 2013; USEPA 2014; Wiener and Spry 1996).

7.2.2.2.3 Pesticide Objectives

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 14 and 15. Pesticide concentrations necessary to protect Chinook salmon and steelhead egg incubation are expected to be similar. Based on the described approach of pesticide environmental objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 16) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

It is estimated salmon exposed to pesticides at a frequency 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control) (Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has similar impact on salmonid physiology and responses across all life stages, then exposures of pesticides greater than 30% (Bin 7-10, Table 16) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2-6, Table 16. See Appendix B, Section 1.3.3.1 for more information.

Mercury objectives for the egg incubation life stage are presented in Table 29. The objectives apply to the mercury concentrations in the eggs themselves, as well as the concentrations in the maternal fish to prevent the transfer of mercury at toxicological levels.

Table 29

Mercury Objectives for Chinook Salmon and Steelhead During the Egg Incubation Life Stage

Condition	Egg and Maternal Ovary mg/kg (wet wt.)	Maternal Fish mg/kg whole body (wet wt.)
Optimal	< 0.02	< 0.20
Sub-optimal	0.02 to 0.10	0.20 to 1.0
Detrimental[1]	> 0.1	> 1.0

Notes:
[1] Sub-lethal impacts to fish are estimated to occur above optimal conditons. Detrimental impacts are assumed to occur at mercury tissue concentrations that are expected to create 25% or greater injury to the fish. A 25% effect or EC25 metric is a consistent threshold to determine chronic toxicity assessments for regulatory compliance (SWRCB 2012).
">" = greater than
"<" = less than
mg/kg = milligram per kilogram
wt. = weight

Selenium objectives for the egg incubation life stage are presented in Table 30. The objectives apply to the selenium concentrations in the eggs themselves, as well as the concentrations in the maternal fish to prevent the transfer of selenium at toxicological levels. In addition, aqueous selenium objectives are presented for lentic and lotic systems to protect aquatic life from bioaccumulating toxic levels of selenium.

Table 30

USEPA Draft National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life

Media Type	Fish Tissue		Water Column	
Criterion Element	Egg/Ovary	Fish Whole Body or Muscle	Monthly Average Exposure	Intermittent Exposure
Magnitude	15.2 mg/kg (dry wt.)	8.1 mg/kg whole body or 11.8 mg/kg muscle (skinless, boneless filet) (dry wt.)	1.3 µg/L in lentic aquatic systems 4.8 µg/L in lotic aquatic systems	$WQC_{int} = \frac{WQC_{30\text{-}day} - C_{bkgrnd}(1 - f_{int})}{f_{int}}$
Duration	Instantaneous measurement	Instantaneous measurement	30 days	Number of days/month with an elevated concentration
Frequency	Never to be exceeded	Never to be exceeded	Not more than once in 3 years on average	Not more than once in 3 years on average

Notes:
From USEPA 2014. These draft criteria are presented to give a relative magnitude of selenium levels above which could pose risks to aquatic life. In addition, the criteria are presented as an example of the type of approach that could be used to assess selenium impacts to aquatic life. The criteria have yet to be peer review, and they have not been promulgated by USEPA.
µg/L = microgram per liter
mg/kg = milligram per kilogram
WQC = Water Quality Criterion
wt. = weight

7.2.2.3 Temperature

7.2.2.3.1 Rationale

Suitable water temperature is necessary for normal behavior, growth, and viability of all life stages of salmonids including the egg incubation stage. Water temperature and developmental rate are tightly and positively correlated (Quinn 2005; Healey 1991); however, beyond certain thresholds, temperature correlates negatively with efficient use of food resources and proper enzymatic functioning. For example, eggs and alevins incubated at temperatures that are either too cold or too warm produce smaller fry than they would at optimal temperatures (USEPA 2001). Temperature-related mortality and habitat-limitation are likely to become even more serious problems for Central Valley salmonids in the future because of global climate change (Lindley et al. 2007).

7.2.2.3.2 Approach

The SEP group relied on water temperature criteria established by the USEPA Region 10 Guidance for Pacific Northwest State Tribal Temperature Water Quality Standards (2003) to identify optimal, sub-optimal, and detrimental water temperature conditions for Chinook salmon. The USEPA (2003) recommends using the 7DADM metric for evaluating temperature impacts on salmonid life stages. The 7DADM metric is the 7-day average of daily maximum water temperatures. The SEP group used water temperature ranges for optimal, sub-optimal, and detrimental to describe the objectives for Chinook salmon and steelhead.

7.2.2.3.3 Objectives

Chinook Salmon

Salmonid eggs and larvae require suitable water temperatures to complete incubation. The length of time it takes for eggs to hatch depends mostly on water temperature. In addition, warm water temperatures can decrease egg survival. USEPA (2003) found that constant temperatures between 4°C to 12°C (39.2°F to 53.6°F) result in good egg survival and that a narrower range (6°C to 10°C [42.8°F to 50°F]) is optimal. In a review, the USFWS (1999 cited by Myrick and Cech 2004) concluded that temperature-related egg mortality in Chinook salmon increased at temperatures above 13.3°C (55.9°F) and this is the limit applied in most regulatory arenas (e.g., NMFS 2009b; SWRCB Order 90-05). A review of research on different populations of Chinook salmon from within and outside of the Central Valley indicated that temperatures between 6°C and 12°C (42.8°F to 53.6°F) were optimal for Central Valley Chinook salmon (Myrick and Cech 2004). Table 31 describes the different water temperature ranges for Chinook salmon.

Table 31
Temperature Objectives for Chinook Salmon Egg Incubation

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Gravel	**Fall-run:** Late October to March **Spring-run:** Late August to March	Optimal	6°C to 12°C (42.8°F to 53.6°F) (Daily Average)
			< 12.5°C (54.5°F) (7DADM)
		Sub-optimal	4°C to 6°C (39.2°F to 42.8°F) (Daily Average)
			12°C to 13.3°C (53.6°F to 55.9°F)(Daily Average)
			12.5°C to 13.8°C (54.5°F to 56.8°F) (7DADM)
		Detrimental	> 13.3°C (55.9°F) (Daily Average)
			> 13.8°C (56.8°F) (7DADM)

Notes:
">" = greater than
"<" = less than
°C°F = degrees Fahrenheit
7DADM = 7-day average of daily maximum temperature

Steelhead

As with Chinook salmon, *O. mykiss* eggs and larvae require cold water to successfully complete incubation. With the construction of impassable dams, *O. mykiss* eggs incubating in the San Joaquin Valley became dependent on cold-water storage in reservoirs. The accessible supply of cold-water storage limits successful spawning habitat for *O. mykiss* populations in the southern Central Valley. There is a serious lack of peer-reviewed studies on the temperature tolerances of Central Valley anadromous *O. mykiss* eggs, and additional study of temperature impacts on this species' eggs is needed (Myrick and Cech 2004). Optimal incubation temperatures for steelhead occur in a narrower range than those for Chinook salmon. Indeed, Myrick and Cech (2004) warned against managing water temperatures for the upper end of the Chinook salmon thermal tolerance range in waterways and during periods when steelhead are also incubating because incubating steelhead cannot tolerate such high temperatures. Richter and Kolmes (2005) concluded that egg mortality increased as incubation temperatures exceeded 10°C (50°F) and substantial mortality may occur when temperatures exceed 13.5°C to 14.5°C (56.3°F to 58.1°F). Based on experience at hatcheries in the Central Valley, optimal incubation temperatures appear to be in the 7°C to 10°C (44.6°F to 50°F) range (Myrick and Cech 2004). California's steelhead management plan (McEwan and Jackson 1996) suggests a slightly higher temperature range (from 9°C to 11°C [48.2°F to 51.8°F). Table 32 describes the water temperature ranges for steelhead.

Table 32
Temperature Objectives for Steelhead Egg Incubation

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Gravel	December to June	Optimal	7°C to 10°C (44.6°F to 50°F) (Daily Average)
			< 10.5°C (50.9°F) (7DADM)
		Sub-optimal	4°C to 6.9°C (39.2°F to 44.4°F) (Daily Average)
			10°C to 13.5°C (50°F to 56.3°F) (Daily Average)
			10.5°C to 14.0°C (50.9°F to 57.2°F) (7DADM)
		Detrimental	> 13.5°C (56.3°F) (Daily Average)
			> 14.0°C (57.2°F) (7DADM)

Note:
">" = greater than
°C°F = degrees Fahrenheit
7DADM = 7-day average of daily maximum temperature

7.2.2.4 Fine Sediment

7.2.2.4.1 Rationale

High levels of fine sediment in spawning gravels are known to negatively affect spawning success (Kondolf 2000). Studies of the effects of fines have often compared levels of fines with percent survival of eggs (e.g., Tappel and Bjornn 1983). There is a great deal of variation in the relationship of fine sediment to egg survival, but Jensen et al (2009) evaluated many of the studies in an attempt to get a common assessment of the information available. This "meta-analysis" identified that the most commonly used size limits for fine sediment are less than 0.85 mm (0.033 in) and less than 4.8 mm (0.189 in). The data they provide for a fine sediment upper limit of 6.4 mm is largely from Tappel and Bjornn (1983), and with the enormous scatter in survival values, it does not appear to improve the evaluation of limits to define optimum conditions. Combining the data from previous studies, they were able to produce curves for several species, including Chinook salmon and steelhead. The data have a large amount of variation in them, but the relationships will allow the development of criteria for maintaining gravel quality for spawning.

7.2.2.4.2 Approach

The values for fine sediment are largely developed from Jensen et al. (2009). It is important to note that data for very low fine sediment values do not support 100% survival of eggs. The y-intercepts of the relationships given in Jensen et al. (2009) indicate the average survival of between 80% and 95% when fines less than 0.85 mm (0.033 in) are at extremely low values. The y-intercepts for the 4.8 mm (0.189 in) fines also are not at 100% and, in fact, are lower than the values for 0.85 mm (0.033 in), which seems counter-intuitive. Variation in egg survival is enormous at those low levels of fines, ranging from approximately 20% to nearly 100%. Using the data, 80% was set as a baseline value for egg survival under a "no fine sediment" condition. It was assumed that no more than a 10% decline from the baseline should be allowed under optimal conditions; thus fine sediment that allows for greater than or equal to 70% egg survival is considered optimal. Sub-optimal conditions are assumed to be between 50% and 70% egg survival. Conditions that equate to less than 50% survival are assumed to be detrimental.

Using the percent survival above, fine sediment values were extracted from the graphs using direct inspection. The curve for all species egg survival versus fine sediment less than 0.85 mm (0.033 in) was used as the curve includes a 95% confidence interval. The lower 95% bound was used to provide the most conservative (minimum) estimate for percent fines.

The resulting inspection results in a 5% fines limit for optimum habitat and a 10% fines limit for suboptimum. Any higher percentage of fines smaller than 0.85 mm (0.033 in) would be considered detrimental.

The data for sediment smaller than 4.8 mm (0.189 in) are less clear. There are results from studies using green eggs and eyed eggs. The results indicate a very different response by the green and eyed eggs with the eyed eggs exhibiting higher survival rates, likely because of their more advanced developmental stage. It is likely that green eggs have lower survival overall because the early developmental stage increases sensitivity to stressful conditions. Overall egg survival is likely controlled by the effects of fine sediment at the more sensitive green egg stage; thus, the green egg curve was used to set fine sediment thresholds for the 4.8 mm (0.189 in) sediment size class. In addition to variation in egg survival due to developmental stage, egg survival for green and eyed eggs varied among studies conducted using different salmonid species. Steelhead green eggs survive show higher survival than Chinook green eggs; however, Chinook eyed eggs show higher survival than steelhead. This was interpreted to mean that the data were highly variable and there is little evidence to support using different survival rates for Chinook and steelhead. Thus, the steelhead curve from the green eggs graph was used, giving 5% fines as the upper limit for optimal conditions and 15% as the upper limit for suboptimal conditions. Anything greater than 15% fines (less than 4.8 mm [0.189 in]) is considered detrimental.

7.2.2.4.3 Objectives

Table 33 provides fine sediment objectives for Chinook salmon and steelhead spawning.

Table 33
Fine Sediment Objectives for Chinook Salmon and Steelhead Spawning (Eggs/Larvae)

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Gravel (measurement must occur in gravel, not water column)	**Fall-run:** Late October to March **Spring-run:** Late August to March **Steelhead:** December to June	Optimal	< 5% smaller than 4.8 mm (0.189 in)
		Sub-optimal	5% to 15% finer than 4.8 mm (0.189 in) or 5% to 10% finer than 0.85 mm (0.033 in)

		Detrimental	> 15% smaller than 4.8 mm (0.189 in) or > 10% smaller than 0.85 mm (0.033 in)

Notes:
">" = greater than
"<" = less than
in = inch
mm = millimeter

7.2.3 Juvenile Rearing and Migration

The juvenile rearing and migration life stage encompasses all of those developmental stages, life-history strategies and associated behaviors and phenotypic expressions that occur subsequent to emergence and prior to either ocean entry (for anadromous forms) or sexual maturation (for resident forms – principally applicable to *O. mykiss*). Depending on the species, these may include but are not limited to, fry, parr, smolt, and yearling developmental stages; anadromous, resident, and estuarine migratory behaviors; and habitat areas both a) within the bank-full channel (in-channel), and adjacent to it on b) higher gradient, shorter inundation off-channel floodplains, floodplain terraces, backwaters, and intermittent side channels (short-inundation floodplains) as well as c) lower gradient, longer inundation valley floodplains and wetlands (long-inundation floodplains).

Generally, optimal conditions for juvenile salmonid rearing involve a balance of the following: a) physical habitat conditions (e.g., temperature, DO, water depth, suitable cover, and substrate); b) ecosystem and foodweb conditions (e.g., prey availability, predator density, and competition),; c) extent of available habitat relative to fish territory size (as a function of fish size, fish density, prey density, and habitat structure); and d) activity levels (as a function of the interaction of (a),(b), and (c) with water velocity) such that juvenile salmonids can sustain metabolic needs while maximizing growth (Quinn 2005). However, these conditions vary across a range of sub-habitat types within the riverine landscape used by juvenile salmonids. Different sub-habitats may also be used differently by different salmonid species, different life-history stages of a given salmonid species (Bradford et al. 2001; Merz et al. in review; and Roper et al. 1994), and individuals within a life-history stage that are developing at different rates (e.g., "young"/small smolts may utilize habitats differently than older/larger ones). In the San Joaquin River basin's Mokelumne River, juvenile Chinook salmon have been shown to prefer off-channel floodplain habitat for rearing while juvenile steelhead prefer in-channel riffle habitat (Merz et al. in review). For a given species, the interaction of different life-history stages with different sub-habitats can additionally reinforce cohort and population-level life-history diversity and associated resilience (McClure et al. 2008; Zimmerman et al. 2015). For example, juvenile Chinook salmon rearing on floodplains can experience greater maximum size, diversity in growth, and exposure to environmental pollutants than juvenile salmon reared in the associated river channel (Sommer et al. 2001, 2005; Jeffres et al. 2008; and Henery et al. 2010). For juvenile steelhead, in-channel rearing habitat with more variable flow has been associated with higher levels of anadromy (Kendal et al. 2015; Pearsons et al. 2008). In characterizing optimal rearing habitat conditions, it is, therefore, appropriate to do so by sub-habitat and species.

Depending on the salmonid species and life-history stage, there may not be a clear delineation between those sub-habitats used for rearing and for migration. For example, the same channel reach may theoretically be used by juvenile *O. mykiss* for rearing at the same time as it is being used for juvenile Chinook salmon as a migration corridor. Similarly, the same valley floodplain area may be used as a migration pathway by an outmigrating juvenile Chinook salmon smolt and a primary rearing area for a Chinook salmon parr. Juvenile Chinook salmon and *O. mykiss* may also continue to rear as they move downstream, whereas Central Valley steelhead seem to move downstream relatively quickly once they begin their emigration from upstream rearing areas.

For the purposes of environmental objectives development, the SEP group characterizes migration as downstream movement in outmigrating anadromous or estuarine juveniles. Optimal migration conditions include physical habitat conditions (e.g., temperature) that support smoltification, allow for passage (e.g., depth, free flowing rivers not obstructed by barriers, partial barriers, or water diversions), and facilitate movement (e.g., velocity) as well as habitat heterogeneity and distribution that support distributed velocity refugia, downstream rearing behavior, and predator avoidance (e.g., turbidity). Rearing and migration habitat are differentiated based on the primary function it is serving to a given individual or species during the time they are occupying it. In cases where a habitat is serving as both rearing and migration functions simultaneously for a given species, optimal conditions for rearing are prioritized. At the same time, the SEP group recognizes that the natural, historic overlap in these functions speaks to their inherent alignment, and within the appropriate range, diversity in conditions within a given sub-habitat type supports life-history diversity and resilience in the population.

7.2.3.1 Rearing and Migration Timing, Habitats, and Associate Parameters

Timing of rearing and migration varies by species and across years, but when considering all three salmonid species covered here, can be presumed to occur year-round. For juvenile fall-run Chinook salmon (fry, parr, and smolt), the rearing and migration period has been defined as extending from the last week of January through the second week of June. For spring-run Chinook salmon, this period extends from the last week of December through the second week of June. For *O. mykiss*, the juvenile rearing period is considered to be year-round. As such a separate rearing period for yearlings has not been defined. However, a specific period has also been identified with different objectives to support smoltification in anadromous life-history forms of *O. mykiss* that extends from December through March.

Rearing and migration environmental objectives have been defined for three primary habitat types as follows:

1. Floodplain – long inundation: This habitat type serves the specific functions of rearing habitat for juvenile Chinook salmon and migration "rest stop" and predator avoidance pathway for juvenile Chinook salmon and *O. mykiss*. It is applicable to the lower section of the river (below Ripon) and characterized by lower gradients and longer seasonal inundation event durations (10 to 21 days) that allow for autochthonous primary and secondary production and result in high prey densities. This productivity is supported by a substrate with a higher proportion of fines, shallower water depths, and lower velocities. As a result of the low velocities and high prey densities, the optimal temperature range and maximum temperature threshold for this habitat are higher.
2. Floodplain – short inundation: This habitat type serves the specific functions of rearing habitat for juvenile Chinook salmon and *O. mykiss* and migration "rest stop" and predator avoidance pathway for juvenile Chinook salmon and *O. mykiss*. It is applicable to the portions of the river above Ripon and characterized by higher gradients and shorter seasonal inundation events (1 to 9) days that support elevated prey densities primarily through allochthonous input of displaced terrestrial

invertebrates and, to a lesser extent, benthic invertebrate drift. As a function of the gradient, velocities are generally higher and substrate coarser, though depths remain lower than in-channel. Optimal temperature range is similar to that of in-channel habitats.

3. In-channel: This habitat type serves the specific functions of rearing habitat for juvenile *O. mykiss* and migration pathways for juvenile Chinook salmon and *O. mykiss*. It is applicable to all portions of the river (including side-channels and braided channels) and characterized by perennial flows and a greater range of depths and velocity than off-channel habitats. Prey densities are generally lower than off-channel habitats and velocities are greater, resulting in a lower temperature range and maximum temperature threshold than long-inundation floodplain habitats. Colder temperatures in this habitat also support smoltification during certain times of year, and variability in flow and temperature support anadromy in *O. mykiss* (Benjamin et al. 2013; Soggard et al. 2012; Pearsosn et al. 2008; Kendall et al. 2015).

As apparent from the descriptions above, several of the critical parameters applied to quantify desired conditions are common to multiple habitat types. Following is a breakdown of desired conditions for each species, organized by parameter, for each applicable habitat type. Tables A-5a through A-5d provide a summary of these environmental objectives.

7.2.3.2 Dissolved Oxygen

7.2.3.2.1 Rationale

Adequate concentrations of DO in water are critical for salmon and steelhead survival. In freshwater streams, hypoxia can impact the growth and development of salmon and steelhead fry as well as the swimming, feeding, and reproductive ability of juveniles. If salmonids are exposed to hypoxic conditions for too long, mortality can result (Carter 2005). Factors affecting DO levels may vary among sub-habitats used during juvenile rearing and migration. On floodplains, DO levels may be spatially variable and driven by factors including temperature, wind mixing, and biological oxygen demand (BOD). In channel, DO is typically less spatially heterogeneous (relative to salmonid needs) and presumed to be driven principally by temperature, with potential influence from groundwater, mixing, and BOD lower in the system.

7.2.3.2.2 Approach

Salmonids may be able to survive when DO concentrations are low (<5 mg/L), but growth, food conversion efficiency, and swimming performance will be adversely affected (Bjornn and Reiser 1991). Davis (1975) reviewed numerous studies and reported no impairment to rearing salmonids if DO concentrations averaged 9 mg/L, while at oxygen levels of 6.5 mg/L "the average member of the community will exhibit symptoms of oxygen distress," and at 4 mg/L, a large portion of salmonids may be affected. WDOE (2002) concludes that a monthly or weekly average concentration of 9 mg/L and a monthly average of the daily minimum concentrations should be at or above 8.0 to 8.5 mg/L to have a negligible effect (5% or less) on growth and support healthy growth rates. USEPA (1986) states that due to the variability inherent in growth studies, the reductions in growth rates seen above 6 mg/L are not usually statistically significant, while reductions in growth at DO levels below 4 mg/L are considered severe. WDOE (2002) recommended that DO levels below 5 to 6 mg/L should be considered a potential barrier to the movement and habitat selection of juvenile salmonids. Given that recommendation, we have established that DO levels below 6.0 mg/L are detrimental for juvenile salmon.

7.2.3.2.3 Objectives

DO objectives for Chinook salmon and steelhead juvenile rearing and migration are provided in Table 34. It is not necessary to separate DO objectives by habitat type because juvenile salmon and steelhead are affected by DO the same whether they are in the main river channel or in the floodplain.

Table 34
DO Objectives for Chinook Salmon and Steelhead Juvenile Rearing and Migration

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
River channel or Floodplain (Water column measurement)	**Fall-run:** Last week of January to 2nd week of June **Spring-run:** Last week of December to 2nd week of June **Steelhead:** January to December (year-round)	Optimal	> than 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)

		Detrimental	< 6 mg/L (Daily Minimum)

Notes:
">" = greater than
"<" = less than
mg/L = milligram per liter

7.2.3.3 Temperature

7.2.3.3.1 Rationale

Juvenile salmonid growth, life-stage duration, and metabolic efficiency are directly influenced by water temperature (Quinn 2005). Several authors have hypothesized that Central Valley populations of Chinook salmon and steelhead may tolerate warmer temperatures than those of other populations (Myrick and Cech 2004). In San Joaquin River basin's Tuolumne River, there is limited evidence of this in *O. mykiss* populations (Farrell et al. 2015). For juvenile salmonids who are actively feeding over a certain range of temperatures, growth increases with increasing temperature as long as food is readily available; increasing temperatures may lead to decreased growth or death when food supplies are not sufficient to support increases in metabolic rate. Temperatures ultimately limit growth and survival at thresholds that are species-, population-, and individual-specific.

Temperatures that produce mortality among Pacific salmon depend, to some extent, on acclimation temperatures—higher acclimation temperatures produce higher Incipient Upper Lethal Temperatures (IULT; Myrick and Cech 2004). Various sources indicate an IULT for Chinook salmon in the range of 24°C to 25°C (75.2°F to 77°F) (Myrick and Cech 2004). Baker et al. (1995) found that Central Valley Chinook salmon had an IULT between approximately 22°C to 24°C (71.6°F to 75.2°F). Negative sub-lethal effects (those that may increase susceptibility to other mortality mechanisms) begin to occur at temperatures lower than the IULT. In the laboratory, when fish have access to full rations, growth of juvenile salmonids increases with temperature up to their physiological limits; however, when food supply is limited (as it often is under normal conditions in the field), optimal and sub-optimal growth and mortality occur at lower temperatures. For example, Mesa et al. (2002) detected increased levels of heat shock proteins (an indicator of stress) after several hours of exposure to 20°C (68°F) for Columbia River fall-run Chinook salmon.

7.2.3.3.2 Approach

Chinook Salmon

Among juvenile fall-run Chinook salmon from California's Central Valley population, Marine and Cech (2004) found decreased growth, reduced smoltification success, and impaired ability to avoid predation at temperatures above 20°C (68°F). They also reported that fish reared at temperatures of 17°C to 20°C (62.6°F to 68°F) experienced increased predation relative to fish raised at 13°C to 16°C (55.4°F to 60.8°F), although they found no difference in growth rate among fish reared in these two temperature ranges. The finding of decreased performance at temperatures above 17°C (62.6°F) is consistent with several studies that suggest, when food supplies are not super-abundant, optimal growth and survival among Chinook salmon occurs at temperatures somewhat lower than 17°C (62.6°F). USEPA (2003) identifies constant temperatures of 10°C to 17°C (50°F to 62.6°F) (and 7DADM less than 18°C (64.4°F) as being optimal conditions for juvenile Chinook salmon when food supplies are limiting. USEPA (2003) recommends 16°C (60.8°F) 7DADM as a maximum criterion to: 1) safely protect juvenile salmon and trout from lethal temperatures; 2) provide upper optimal conditions for juvenile growth under limited food during the period of summer maximum temperatures and optimal temperatures for other times of the growth season; 3) avoid temperatures where juvenile salmon and trout are at a competitive disadvantage with other fish; 4) protect against temperature induced elevated disease rates; and 5) provide temperatures that studies show juvenile salmon and trout prefer and are found in high densities. Based on this recommendation, 16°C (60.8°F) 7DADM or less has been established as the optimal water temperature for juvenile rearing and migration in the river channel.

As indicated, the temperatures that can be tolerated by rearing juvenile Chinook salmon depend to a great extent on food availability. USEPA (2003) indicates that, when food supplies are unlimited, temperatures from 13°C to 20°C (55.4°F to 68°F) (constant) may be optimal. Recent studies on Central Valley Chinook salmon rearing on inundated floodplains reveal excellent survival and growth rates at even higher temperatures. Growth and survival for limited periods have been recorded at temperatures as high as approximately 25°C (77°F) (Katz unpublished data; Jeffres unpublished data). The increased tolerance for high temperatures in these fish is believed to be related to the high prey densities and food quality available on floodplains, coupled with low activity costs (Sommer et al. 2001; Henery unpublished data) and suggests that when food is not limiting, Chinook salmon can tolerate and even thrive at temperatures approaching the physiological limits observed in the laboratory (i.e., IULT). As a result, the SEP group assumed that, following successful restoration of floodplain habitats (and during periods when juvenile Chinook salmon actually occupy inundated floodplains), rearing Chinook juvenile salmon could survive temperatures approaching 25°C (77°F) for limited periods of time. Based on these distinctions, temperatures greater than 25°C were established a detrimental for salmon rearing on long-inundation floodplains only. However, the SEP group also recognizes that exposure to such warm water temperatures greatly increases disease risk, and stress from other water quality factors (e.g., DO or contaminants) likely reduces thermal tolerance. When Chinook salmon are not in habitats that support super-abundant food resources (e.g., in-channel habitats), lower temperatures are required to avoid negative sub-lethal effects.

Elevated water temperatures can inhibit the parr-smolt metamorphosis (smoltification) in salmonids. Chinook salmon can smolt at temperatures ranging from 6°C to 20°C (42.8°F to 68°F) (Myrick and Cech 2004). However, salmon that smolt at higher temperatures (greater than 16°C [60.8°F]) tend to display impaired smoltification patterns and reduced saltwater survival (Myrick and Cech 2004). Marine and Cech (2004) found that Central Valley Chinook salmon rearing in temperatures greater or equal to 20°C (68°F) suffered altered smolt physiology, and other studies from within this ecosystem suggest that negative effects of temperature on the parr-smolt transition may occur at temperatures less than 20°C (68°F). Richter and Kolmes (2005) cite two studies that indicated negative impacts on Chinook salmon smoltification success at temperatures greater than 17°C (62.6°F). USEPA (2003) indicates that smoltification impairment may occur at temperatures between 12°C to 15°C (53.6°F to 59°F).

Steelhead

Laboratory studies show that incipient lethal temperatures for juvenile steelhead occur in a range between 27.5°C to 29.6°C (81.5°F to 85.3°F), depending on acclimation temperatures (Myrick and Cech 2005). Temperature influences both growth and lipid content in *O. mykiss* (McMillan et al. 2012). Optimal temperatures for steelhead juvenile growth occur between 15°C to 19°C (59°F to 66.2°F) (Moyle 2002; Richter and Kolmes 2005). In addition to growth, temperature may also influence *O. mykiss* ecological interactions and life-history

(Reese and Harvey 2002; Kendal et al. 2015). For example, steelhead juveniles suffer adverse impacts of competition with pike minnow at temperatures greater than 20°C (68°F), though no competitive impact is detectable at lower temperatures (Reese and Harvey 2002). Temperature has been correlated with anadromy versus residency in juvenile *O. mykiss* (Kendal et al. 2015) with warmer temperatures associated with anadromy in some (Benjamin et al. 2013; Sogard et al. 2012), but not all cases (Doctor et al. 2014). The variable nature of these correlations does not support the use of temperature objectives in isolation as a mechanism for promoting anadromy.

Steelhead may be particularly sensitive to high temperatures during the smoltification process. USEPA (2003) indicates that temperatures greater than 12°C (53.6°F) inhibit steelhead metamorphosis into smolt. Richter and Kolmes (2005) and USEPA (1999) cited studies that present a range of temperatures between 11°C to 14°C (51.8°F to 57.2°F) that may inhibit steelhead smoltification. Myrick and Cech (2005) cautioned that smolting steelhead in the Central Valley must experience temperatures less than 11°C (51.8°F) to successfully complete this metamorphosis. The critical temperature at which smoltification becomes inhibited may vary from run-to-run (Richter and Kolmes 2005).

7.2.3.3.3 Objectives

Temperature objectives for juvenile rearing and migration life stages for Chinook salmon and steelhead are provided below in Table 35.

Table 35

Temperature Objectives for Chinook Salmon and Steelhead Juvenile Rearing and Migration

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Channel	**Fall-run:** Last week of January to 2nd week of June **Spring-run:** Last week of December to 2nd week of June **Steelhead:** January to December (year-round)	Optimal	6°C to 16°C (42.8°F to 60.8°F) (7DADM)
		Sub-optimal	17°C to 20°C (62.6°F to 68°F) (7DADM)
		Detrimental	> 20°C (68°F) (7DADM)
Floodplain – Short Inundation		Optimal	10°C to 18°C (50°F to 64.4°F) (7DADM)
		Sub-optimal	18°C to 20°C (64.4°F to 68°F) (7DADM)
		Detrimental	> 20.0°C (68°F) (7DADM)
Floodplain – Long Inundation		Optimal	10°C to 18°C (50°F to 64.4°F) (7DADM)
		Sub-optimal	18°C to 25°C (64.4°F to 77°F) (7DADM)

		Detrimental	> 25°C (77°F) (7DADM)
Channel	**Steelhead (Smoltification):** December to March	Optimal	11°C (51.8°F) (Weekly Average)
			12.5°C (54.5°F) 7DADM
		Detrimental	> 11°C (51.8°F)(Weekly Average)
			> 12.5°C (54.5°F) (7DADM)

Notes:
">" = greater than
°C°F = degrees Fahrenheit
7DADM = 7-day average of daily maximum temperature

7.2.3.4 Inundation

7.2.3.4.1 Rationale

The flood pulse and seasonal inundation of floodplains drive key hydrologic and geomorphic processes that provide substantial habitat and trophic benefits to river ecosystems and fish (Junk 1989; Junk et al. 2004; and Poff et al. 2010). The action of floodplain inundation and the extension of the photic zone it creates have been shown to enhance phytoplankton biomass (Schemel et al. 2004; Sommer et al. 2004; and Ahearn et al. 2006), zooplankton growth (Müller-Solger et al. 2002; Grosholz and Gallo 2006), and drift invertebrate biomass (Sommer et al. 2001a, 2001b; Benigno and Sommer 2008). Greater frequency of inundation has also been linked to higher levels of invertebrate productivity (Boulton 2012; Grosholz and Gallo 2006). It is therefore not surprising that juvenile Chinook salmon rearing on floodplains and other off-channel habitats tend to be larger and in better physical condition than those that rear in the main channel of rivers (Sommer et al. 2001; Jeffres et al. 2008; Limm and Marchetti 2009; and Henery et al. 2010).

In higher gradient off-channel and floodplain habitats, short duration inundation can displace terrestrial invertebrates from soil and vegetation, and drive terrestrial invertebrate distribution by modifying heterogeneity of organic matter (Langhans 2006). In low gradient floodplains, longer inundation times and extended solar exposure can stimulate autochthonous primary and secondary production that can drive high prey densities and fish production (Grosholz and Gallo 2006). Research from the Cosumnes River floodplain found that secondary productivity began to increase in as little as 10 days after inundation (Jeffres unpublished data) and reached high levels at approximately 14 days (Grosholz and Gallo 2006). A similar pattern was observed in the Yolo Bypass Floodplain (Katz unpublished data). Research in the Yolo Bypass further indicates that after approximately 21 days, productivity levels have stabilized or are in decline (Katz unpublished data), and Grosholz and Gallo (2006) recommend a 2 to 3 week flooding duration and frequency to best support native fish.

The timing of inundation, both on its own and through its interaction with duration and frequency, also exerts significant influence over floodplain habitat quality for salmonids. On an annual time scale, under unimpaired flow conditions, inundation event frequency is often tied closely with water year type, and many habitats may not inundate during dryer years. In order for rearing habitat benefits to be realized for a given cohort, inundation must occur in 1 out of every 2 years (assuming a yearling strategy in some percentage of out-migrants). At a daily time scale, for short duration inundation events, where displacement of terrestrial invertebrates is a main prey source, the frequency of inundation drives the timing of both habitat availability and increased prey density. For longer inundation events, autochthonous production may continue to increase during a single event, primarily as a function of duration (Grosholz and Gallo 2006). Research from both the Yolo Bypass and Cosumnes floodplains, however, indicate that drawdown between events can reset the productivity cycle once productivity rates have begun to stabilize or decline (Grosholz and Gallo 2006; Katz unpublished data).

7.2.3.4.2 Approach

Inundation objectives presented here apply habitat type specific inundation event duration and timing as a surrogate for mechanism and extent of food production and availability (assuming other identified parameters/conditions including temperature, water quantity, and substrate type). Specifically, short duration inundation events are assumed to have elevated levels of invertebrate drift (benthic and terrestrial) as primary prey source, whereas long inundation events are assumed to have autochthonous secondary productivity as a primary prey source, with terrestrial and benthic invertebrate drift as a secondary source. Duration of discrete events are measured based on a period following a minimum drawdown time. Minimum annual frequency has been established based on the potential for floodplain rearing benefits to have been experience by adults in any given year, assuming a mix of primarily 2- and 3-year-old retuning adults.

7.2.3.4.3 Objectives

Specific objectives for inundation for juvenile Chinook salmon and steelhead rearing are provided in Table 36.

Table 36
Environmental Objectives for Inundation for Juvenile Chinook Salmon and Steelhead Rearing

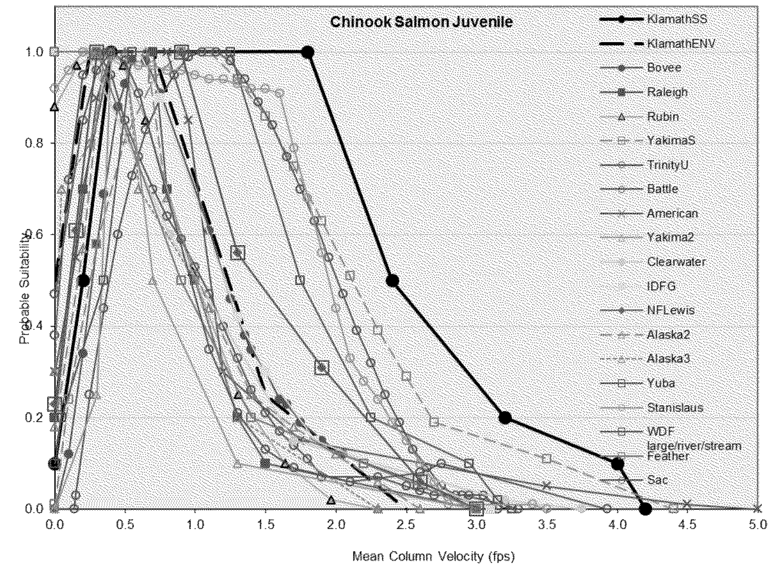
Spatial Extent (Habitat Type)	Temporal Extent	Parameter	Range (Metric)
Floodplain – Long Inundation	**Fall-run:** Last week of January to 2nd week of June **Spring-run:** Last week of December to 2nd week of June **Steelhead:** January to December (year-round)	Duration	10 to 21 wetted acre days
		Frequency	Minimum of 1 in 3 years recurrence interval Minimum of 1 week drawdown to distinguish discrete event
Floodplain – Short Inundation		Duration	1 to 9 wetted acre days
		Frequency	Minimum of 2 in 3 years recurrence interval during all years; (minimum of 1 week drawdown to distinguish discrete event); Minimum of 1 event per year in wet years/years where inundation occurs

7.2.3.5 Water Depth and Velocity

7.2.3.5.1 Rationale

Both depth and velocity of flow play a critical role in habitat quality for juvenile salmonids. Water depth and water velocity are parameters commonly applied to habitat suitability models for juvenile salmonids, and different combinations of water velocity and depth can contribute to habitat physical and ecological functions as well as heterogeneity both within and across habitat types. For juvenile salmonids, water velocity is a key driver of activity level, which interacts with temperature, DO, and prey availability driven consumption rate to affect growth rate (see Section 1.3.5.3 above), and suitable depths support foraging behavior and predator avoidance (Gregory 1993). Optimal depth and velocity for juvenile salmonids can vary significantly between systems and for fish of different sizes (Figure 10). Research on juvenile Chinook salmon rearing on flooded rice fields in the Yolo Bypass found no significant correlation between depth and growth for depth ranges of approximately 0.15 m to 0.61 m (6 in to 2 ft) at low velocities and a consistent prey density (Katz unpublished data).

A) Velocity



B) Depth

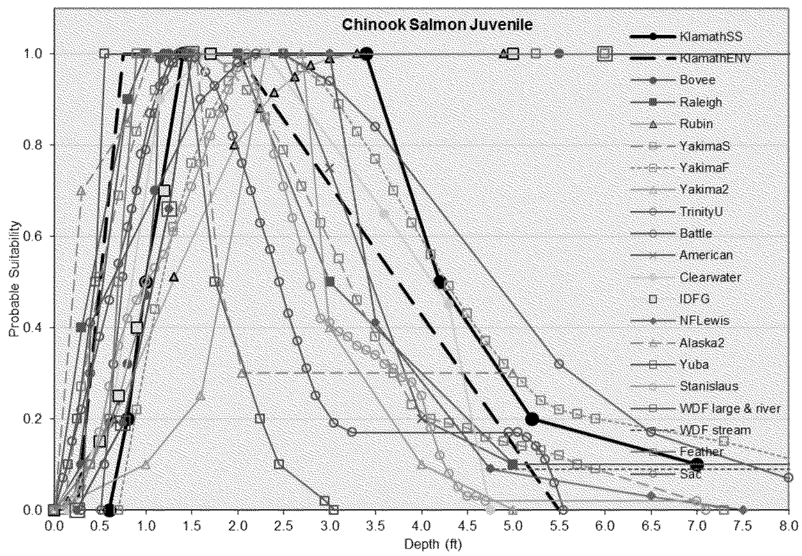


Figure 10

Habitat Suitability Index Values for A) Velocity and B) Depth for Juvenile Chinook Salmon on Multiple Rivers

Note:
Compiled by SJRRP (2012) from multiple published and unpublished empirical (when available) and modeled datasets. Note the Stanislaus River (teal circles).

7.2.3.5.2 Approach

Juvenile Chinook salmon habitat suitability models for depth and velocity have been developed previously for the Stanislaus River (Aceituno 1990) and applied to floodplain habitat estimates for the San Joaquin River (SJRRP 2012). These estimates suggest optimal depth values between 0 m and 1.4 m (0 ft and 4.5 ft) in floodplain or off-channel conditions (Aceituno 1990; SJRRP 2012). The same studies assigned optimal velocity values for those habitat types at between 0 m/s and 0.91 m/s (0 ft/s and 3 ft/s) (Aceituno 1990). These values are based on the velocity requirement for Chinook salmon. While the needs of *O. mykiss* may be different and may use short inundation off-channel habitats for rearing under certain circumstances, research suggests that their primary rearing habitat is in-channel (Merz et al. in review). The SEP group has therefore used values supporting Chinook salmon as the basis for floodplain objectives. Depth and velocity objectives have been defined consistently across both short and long inundation floodplains, with the additional guidance that shorter inundation floodplains may exhibit higher velocities as a function of gradient and more confined channel geometry; productivity on longer inundation floodplains, by contrast, may benefit from slower velocities often associated with longer hydraulic residence times.

Water velocity in-channel is generally assumed to be greater than off-channel, flow dependent, and variable within and across years as well as variable at a sub-habitat scale as a function of habitat structure. Additionally, in-channel habitat may be used simultaneously by multiple species and life-history stages. As such, no single velocity or velocity range objective was defined for in-channel habitat. Increased flow variability during the summer has been correlated with higher levels of anadromy in juvenile *O. mykiss* (Kendal et al. 2015; Pearsons et al. 2008), whereas increased residency has been hypothesized (Cramer et al. 2003; McMillan et al. 2007; and Pearsons et al. 1993) to be linked with more stable summer high flows and correlated with increased summer flows in females (Berejikian et al. 2013). Flow variability in the Stanislaus River has declined significantly from historic unimpaired conditions under reservoir operations (Figure XX). To support anadromy in juvenile *O. mykiss*, the SEP group has additionally defined a flow variability objective for in-channel habitat.

7.2.3.5.3 Objectives

Water depth and velocity objectives for Chinook salmon and steelhead juveniles are provided in Table 37.

Table 37
Water Depth and Velocity Objectives for Chinook Salmon and Steelhead Juvenile Rearing

Spatial Extent (Habitat Type)	Temporal Extent	Parameter	Condition	Range (Metric)
Floodplain – Short Inundation	**Fall-run:** Last week of January to 2nd week of June **Spring-run:** Last week of December to 2nd week of June **Steelhead:** January to December (year-round)	Depth	Optimal	0.15 m to 1.22 m (0.5 ft to 4 ft) Averaged spatially
			Sub-optimal	1.23 m to 2.13 m (4 ft to 7 ft) Averaged spatially
		Velocity	Optimal	0 m/s to 0.9 m/s (0 ft/s to 3 ft/s)
			Sub-optimal	> 0.9 m/s (3 ft/s)
Floodplain – Long Inundation		Depth	Optimal	0.15 m to 1.22 m (0.5 ft to 4 ft) Averaged spatially
			Sub-optimal	1.23 m to 2.13 m (4 ft to 7 ft) Averaged spatially
		Velocity	Optimal	0 m/s to 0.9 m/s (0 ft/s to 3 ft/s) s
			Sub-optimal	> 0.9 m/s (3 ft/s)
Channel		Flow variability	Optimal	TBD (X to X applicable during X time of year)

Notes:
">" = greater than
ft = foot
ft/s = foot per second
m = meter
m/s = meter per second

7.2.3.6 Cover, Structure, and Substrate

7.2.3.6.1 Rationale

Structure, cover, and substrate are core components of the physical habitat for juvenile salmonids that can interact with other physical habitat components (e.g., water velocity), and ecosystem dynamics (e.g., primary and secondary productivity, predator-prey interactions) to influence habitat use by juvenile salmonids. Cover and structure, specifically, have been correlated with the density in juvenile salmonids (McMahon and Hartman 1989), and substrate remediation in the form of gravel augmentation has been correlated with increased habitat use by juvenile salmonids in the Merced River (Selheim et al. 2015).

7.2.3.6.2 Approach

As concepts, cover and structure have significant overlap, encompassing a range of common physical elements and differing primarily based on the function they serve for juvenile salmonids. For example, a root wad might be considered cover when the function it is serving is to provide juveniles with refuge from predators or high flows, and structure when the function it is serving is to increase habitat complexity, regulate territory size, or provide a base for invertebrate prey to cling to. Similarly, for juvenile fish, substrate of a certain size (e.g., large cobble or boulders) can provide both cover and structure.

Many studies have examined a range of physical structures definable as "cover" in terms of the extent to which they support suitable habitat for juvenile salmonids (Hampton 1988; Raleigh 1986; Sutton 2006; and WDFW and WDOE 2004). Physical structures constituting cover are not addressed consistently across these studies, and suitability scores for common cover types are also not consistent. In 2012, the San Joaquin Restoration Program developed a summary of habitat suitability scores for cover from multiple sources for use in modelling suitability of floodplain rearing habitat (Table 38; SJRRP 2012). Average habitat suitability index (HSI) scores from this summary were applied as the basis for floodplain rearing habitat cover objectives.

Table 38
Summary of Habitat Suitability Index Scores for Juvenile Salmon Cover

Cover Type	HSI score for each cover type				Average HSI Value
	Raleigh 1986	Sutton 2006	WDFW and WDOE 2004	Hampton 1988	
No Cover	0.01	N/A	0.1	0.1	0.07
Woody Debris	0.9	0.6	N/A	0.7	0.73
Cobble/Boulder	0.2	0.5	N/A	0.18	0.29
Grass	N/A	0.5	0.48	N/A	0.49
Gravel	0.25	0.3	N/A	N/A	0.28
Willow	N/A	0.8	N/A	N/A	0.80
Undercut Bank	1	1	1	1	1.00
Aquatic Vegetation	0.3	0.6	1	0.5	0.60
Overhanging Vegetation	0.38	0.8	1	0.1	0.57
Root Wad	N/A	0.7	1	0.7	0.80

Notes:
Summary of habitat suitability index scores for juvenile salmon, from a range of sources, developed for application to assessment of floodplain habitat quality by the San Joaquin Restoration Program (SJRRP 2012).
HSI = habitat suitability index
N/A = not available
Hampton 1988
Raleigh 1986
Sutton 2006
WDFW and WDOE 2004

Substrate objectives were defined separately for short inundation floodplain, long inundation floodplain, and in-channel habitat types. Substrate objectives are defined broadly to comport with the habitat gradient and target velocity range as well as supporting vegetative cover establishment and the hypothesized assumed productivity mechanisms. For in-channel habitats areas, to the extent that spawning and rearing areas overlap spatially, substrate should be defined based on needs for spawning and egg incubation and emergence. However, substrate objectives for in-channel rearing habitat have additionally been provided here and are applicable to those in-channel areas not targeted for spawning.

7.2.3.6.3 Objectives

Substrate, cover, and structure objectives for juvenile Chinook salmon and steelhead are provided in Table 39.

Table 39
Substrate, Cover, and Structure Objectives for Juvenile Chinook Salmon and Steelhead Rearing

Spatial Extent (Habitat Type)	Temporal Extent	Parameter	Condition	Range (Metric)
Floodplain – Short Inundation	**Fall-run:** Last week of January to 2nd week of June **Spring-run:** Last week of December to 2nd week of June **Steelhead:** January to December (year-round)	Substrate	Optimal	> X% cobble/ gravel < X% fines
		Cover	Optimal	Average HSI score of ≥ 0.5 or: Woody debris ≥ 0.9 Cobble boulder ≥ 0.5 Overhanging vegetation ≥ 0.8 Root wad ≥ 1
Floodplain – Long Inundation		Substrate	Optimal	> X% fines
		Cover	Optimal	Average HSI score of ≥ 0.5

Channel		Substrate	Optimal	> X% cobble/gravel < X% fines

Note:
HSI = habitat suitability index
“>” = greater than
“<” = less than
“≥” = greater than or equal to

7.2.3.7 Spatial Extent and Distribution of Rearing and Migration Habitat

7.2.3.7.1 Rationale

In order for biological objectives to be achieved, spatial extent of rearing habitat must be sufficient to support the combined habitat needs of all rearing juveniles within the system necessary to achieve biological objectives.

Juvenile Chinook salmon either defend or rely on food from an area of territory (Cramer and Ackerman 2009), even when schooling (Neuswanger 2014). Additionally, territory size is thought to limit the density and production of stream-dwelling salmonids (Chapman 1966; Allen 1969; Grant and Kramer 1990). Territory size requirements of individual fish of a given size tend to be constant regardless of the local numbers of fish (abundance; Cramer and Ackerman 2009; Grant and Kramer 1990), and in natural systems result in competition for space and displacement of smaller/weaker individuals (Titus 1990; Keeley 2001; Keeley 2003; Cramer and Ackerman 2009). Smaller/weaker individuals in turn occupy sub-optimal territories (Titus 1990; Keeley 2001) and are likely to experience increased stress, which may reduce growth and fitness, and increased mortality. Providing adequate quantity and quality of territory during rearing and emigration may therefore reduce the negative effects associated with competition for space (SJRRP 2012).

An important component of territory size is the relationship between territory size and fish body size, also known as the “allometry of territory size” (Grant and Kramer 1990). Because salmonids in streams defend territories, from small (post-emergent) juveniles until they either become ocean-ready fish (smolts) or become sexually mature, they must increase the area they defend to meet increasing food and energy (energetic) requirements as they grow (Keeley and Slaney 1996). The result is a dynamic where territory requirements expand through time for growing fish, while fish numbers are diminishing. The required extent and distribution of rearing and migration habitat for juvenile salmonids can therefore be conceptualized as a function of their abundance, size, emigration speed, and survival rate. From this perspective, rearing habitat needs vary based on location and time, where the rearing habitat extent necessary in any one location is equivalent to that which is required by the maximum number of juvenile fish that will occupy that habitat on any day during the rearing and emigration period.

Grant and Kramer (1990) provided a general multi-species (interspecific) regression model for allometric territory size that attempts to account for variability among species. Following the rational above, allometric territory size relationships may be applied as a predictor of space requirements and maximum densities of juvenile salmonids in streams.

7.2.3.7.2 Approach

To establish objectives for spatial extent and distribution of rearing habitat, the Emigrating Salmonid Habitat Estimation (ESHE) model, developed by Cramer Fish Sciences and The Nature Conservancy (SJRRP 2012), was applied. The ESHE model simulates stationary growth (rearing) and downstream movement (emigration) of individual, daily groups (cohorts) of juvenile spring-run and fall-run Chinook salmon (*O. tschawytscha*). The model tracks their numbers (abundance), average speed, size, the amount of territory needed per fish (territory size), and ultimately the amount of suitable habitat required to sustain the number of juvenile salmon present within a model reach. Model outputs provide daily estimates of the number of juvenile spring-run and fall-run Chinook salmon present in each model reach and the required area of suitable habitat needed to support them throughout the rearing and emigration period. A detailed description of the ESHE model is presented in Appendix C.

The ESHE model applies multiple parameters (and associated functions) in order to calculate juvenile salmon abundance and habitat needs of daily cohorts, including:

- Initial abundance – the number of juvenile Chinook salmon entering the model based on the target number of reproducing parent fish
- Initial timing and size – the number of fish on each day that exit the spawning grounds and the average size of the fish exiting the spawning grounds
- Migration speed – the daily downstream movement of juvenile salmon in each reach

- Survival rate – the number of fish that avoid death each day in each reach
- Growth – the daily growth and resulting size of juvenile salmon in each reach
- Territory size – territory size requirements of juvenile salmon in each reach based on their size
- Required suitable habitat – the required suitable habitat needed to support the juvenile salmon present in each reach

The values for each of the parameters described above were populated based on a combination of measured and modeled data. Whenever possible and appropriate, preference was given to measured data from the Stanislaus River. A summary of key model inputs is provided in Table 40.

Table 40
Summary of Key ESHE Model Inputs Along With Sources and Notes

Parameter	Value	Source	Notes
Number of Reproducing Fish	Target: 12,500 (FR); 12,500 (SR) Current: 4,000 (FR)	CVPIA estimated average	Spawner abundance
Female Fish Percentage	50%	SEP group	
Number of Eggs per Fish (fecundity)	5,600	Quinn 2005	
Egg Survival to Emergence	0.90%	Tappel and Bjornn 1983	
Yearlings Percentage	10%	SJRRP 2012	
Entry Numbers and Location	RM 58-54 (25.64%) RM 53-49 (40.98%) RM 53-49 (13.46%) RM 43-39 (8.77%) RM 38-34 (11.15%)	Giudice 2014	Based on redd and female carcass distribution
Migration Speed – Pre Smolts	4.14, 12.62, or 24.91 km/day (2.57, 7.84, or 15.48 mi/day)	XX	
Migration Speed – Smolts	7.11, 18.55, or 35.13 km/day (4.42, 11.53, or 21.83 mi/day)	XX	
Downstream Survival (per km)	Fast = 0.971 Slow = 0.961	SEP group	Calculated based on survival rate
Growth	N/A (Curve)	Fisher 1992	
Territory Size to Fish Size Relationship	N/A	Grant and Kramer 1990	

Habitat Quality	100%	Per SJRRP (2012), measured habitat quality of inundated acres varied from 7% to 30% by reach; but habitat quality on Stanislaus is likely higher	To estimate total inundated area, habitat area needed should be increased based on percentage of functional acres vs. inundated acres

Notes:
CVPIA = Central Valley Project Improvement Act
FR =Fall-Run
km = kilometer
mi = mile
N/A = not applicable
RM = river mile
SEP = Scientific Evaluation Process
SR =Spring-Run

In order to provide habitat spatial extent and distribution objectives that would: a) account for differences in rearing and migration behavior across wet and dry years; and b) be applicable to cohort abundance consistent with both existing population sizes and target population sizes, separate ESHE model runs were completed for current and target population levels under both slow and fast outmigration scenarios (four total model runs). Results from the model runs are presented in Table 41.

It is important to note that model results assume 100% habitat suitability. However, actual habitat suitability within a given area of rearing habitat may be significantly lower. As a component of their floodplain habitat needs analysis, the San Joaquin Restoration Program compiled and examined on-the-ground information on habitat condition from the San Joaquin River basin and found that floodplain habitat suitability ranged from 7% to 30% (SJRRP 2012). Relating the estimated habitat area need provided by ESHE to the percentage of habitat suitability on-the-ground therefore yields the required rearing habitat area. An example to this effect is provided in Table 41.

Table 41
Summary of Key ESHE Model Inputs Along With Sources and Notes

ESHE Results			
Abundance	**Migration Type**	**Habitat Area (m^2)**	**Habitat Area (Acres[2])**
Current	Fast	71,501.68	17.67

Current	Slow	27,5120.3	67.98
Target	Fast	44,7023.35	110.46
Target	Slow	1719,829.92	424.98
Estimated Inundated Area (Example)			
Habitat Quality	**Abundance**	**Migration**	**Inundated Area (Acres)**
7% to30% (SJRRP 2012)	Target	Slow	1416.6 - 6071.1

Notes:
Rearing habitat needs outputs from the ESHE model for slow current and target Chinook salmon populations at slow and fast emigration rates. Habitat area needs estimates assume 100% suitability. The *Estimated Inundated Area (Example)*, applies the measured range of on the ground habitat suitability from the San Joaquin River to the highest output (Target/Slow) from the four modeled scenarios as an example of how ESHE estimated habitat extent objectives translate into habitat extent needs on the ground.
m^2 = square meter

In order to account for differences among years, rearing habitat spatial extent objectives were established based on the range of 100% suitable habitat area needs estimated across the four modeled scenarios. Calculating on-the-ground habitat spatial extent needs for the Stanislaus River will require the application of this range to applicable on-the-ground percent habitat suitability. Habitat distribution objectives were similarly presented as a range, describing the range in percent of the total habitat area necessary in any given reach. Rearing habitat spatial extent and distribution needs were calculated based on targets for spring- and fall-Chinook salmon and are intended to apply primarily to floodplain rearing habitat.

7.2.3.7.3 Objectives

Spatial extent and distribution objectives for rearing and migrating juvenile Chinook salmon and steelhead are provided below in Table 42.

Table 42
Spatial Extent and Distribution Objectives for
Juvenile Chinook Salmon and Steelhead Rearing and Migration

Spatial Extent (Habitat Type)	Temporal Extent	Parameter	Condition	Range (Metric)
Floodplain (combined)	**Fall-run:** Last week of January to 2nd week of June **Spring-run:** Last week of December to 2nd week of June **Steelhead:** January to December (year-round)	Extent	Optimal	71,502 m^2 to 1,719,830 m^2 (17.7 acres to 425 acres)

Floodplain – Short Inundation		Distribution	Optimal	Upstream of Goodwin: ≥ X Goodwin to Knights Ferry: ≥X Knights Ferry to Oakdale: ≥ X Oakdale to Riverbank: ≥ X Riverbank to Ripon: ≥ X
Floodplain – Long Inundation		Distribution	Optimal	Ripon To Caswell: ≥ X% Caswell to Confluence: ≥ X%

Notes:
"≥" = greater than or equal to
m^2 = square meter

7.2.3.8 Contaminants

7.2.3.8.1 Rationale

Like the other life-stages, contaminants have the high potential to impact juvenile rearing and migration. In fact, the greatest impact that contaminants may have is to the health and survival of the juvenile rearing and migration life-stages. For example, herbicides and insecticides are designed to target the organisms at the base of the food web that rearing salmonids rely on. In addition, pesticides have been found to disrupt fish behaviors and biochemistry necessary for survival at this life stage (e.g., predator avoidance, feeding, osmoregulation, and orientation) (Potter and Dare 2003; Scott and Sloman 2004). Furthermore, the nearshore, low-flow habitats that provide the greatest benefit to rearing and migratory juveniles typically have higher concentrations and loads of pesticides, which compounds the impact on salmonids in their preferred habitat (NMFS 2008, 2009c, 2011c). Finally, juvenile salmonids exposed to pesticides and other olfactory inhibiting contaminants during development may fail to imprint to their natal waters, which can lead to increased adulthood straying (NMFS 2009c).

Because of the short time period and the type of food web that juvenile salmonids use during rearing and migration, there is typically low risk to mercury and selenium toxicity. However, there are some instances where environmental condition may stimulate methylmercury production and pose toxicological risks to rearing and migrating juveniles. For example, in 2006 episodic flooding in the San Joaquin River watershed, Delta, and other Central Valley river basins created conditions where YOY fish methylmercury concentrations increased 4- to 5-fold higher than typical concentrations and to levels that could pose risks to fish health (Slotton et al. 2007).

See Appendix B, Section 1.3 for more detailed information on effects of pesticides, mercury, and selenium.

7.2.3.8.2 Approach

Similar to the previous life stages, the SEP group relied on adopted numeric water quality objectives for pesticides from the Sacramento and San Joaquin River Water Quality Control Plan, and proposed pesticide water quality objectives from developing pesticide control programs (CVRWQCB 2011, 2014, 2015) to determine pesticide levels that should provide no adverse impacts to juvenile rearing and migration life stages. In addition, for pesticides that do not have state or federally promulgated objectives or criteria, the SEP group used the USEPA OPP aquatic-life benchmarks with a level of concern for impacts to endangered and threatened species as the safe level for pesticides.

Additionally, no regular pesticide monitoring program exists in the juvenile rearing and migration reach, nor is there likely a program that will exist in the future that will be able to monitor all possible pesticides that may adversely impact rearing and migrating juveniles in the Stanislaus River. Consequently, the SEP group has relied on the Hoogeweg et al. (2011) pesticide prediction model to estimate the current frequency of pesticide water quality objective or benchmark exceedances to categorize optimal, sub-optimal, and detrimental conditions for juvenile rearing and migrating pesticide environmental objectives (see Appendix B, Section 1.3.3.1, for further information). Models, monitoring, toxicity bioassays, and other information will need to be updated, developed, conducted, and further gathered as needed in the future to determine if pesticide concentrations are still adversely impacting salmonid juveniles in the Stanislaus River.

The approachs for selenium and mercury environmental objectives are similar to egg incubation life-stages. The SEP group relied on the draft USEPA National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life (2014) for the environmental objectives to protect salmonid species in the Stanislaus River against adverse effects. The criteria have yet to be promulgated; however, the criteria are consistent with the relevant technical literature on selenium toxicology. The environmental objective should be reevaluated once the USEPA selenium criteria are finalized. No criteria have been developed for the protection of fish from mercury impacts. However, in recent literature, researchers have developed fish tissue mercury concentration benchmarks that are estimated to be protective of adult and juvenile Chinook salmon and steelhead (see Appendix B, Section 1.3.2.2). The SEP group relied in these benchmark concentrations as the level that would be fully protective of salmonids during their juvenile rearing and migration stages.

7.2.3.8.3 Objectives

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 14 and 15. Pesticide concentrations necessary to protect Chinook salmon and steelhead juvenile rearing and migration are expected to be similar. Based on the described approach of pesticide environmental objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 16) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

It is estimated salmon exposed to pesticides at a frequency 30% of the time would reduce juvenile growth through olfaction disruption enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control) (Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Consequently, exposures of pesticides greater than 30% (Bin 7-10, Table 16) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2-6, Table 16. See Appendix B, Section 1.3.3.1 for more information.

Mercury objectives for juvenile rearing and migration for Chinook salmon and steelhead are presented in Table 43. See Appendix B, Section 1.3.3.2 for more information.

Table 43
Mercury Objectives for Chinook Salmon and Steelhead for Juvenile Rearing and Migration

Condition	Juvenile Fish mg/kg whole body (wet wt.)
Optimal	< 0.20
Sub-optimal	0.20 to 1.0
Detrimental[1]	> 1.0

Notes:
[1] Sub-lethal impacts to fish are estimated to occur above optimal conditons. Detrimental impacts are assumed to occur at mercury tissue concentrations that are expected to create 25% or greater injury to the fish. A 25% effect or EC25 metric is a consistent threshold to determine chronic toxicity assessments for regulatory compliance (SWRCB 2012).
">" = greater than
"<" = less than
mg/kg = milligram per kilogram
wt. = weight

Selenium objectives for the rearing and migration life stage are presented in Table 30. The objectives apply to the selenium concentrations in the juvenile fish tissue. In addition, aqueous selenium objectives are presented for lentic and lotic systems to protect rearing and migrating juvenile salmonids from bioaccumulating toxic levels of selenium.

7.1 Summary and Visualization

Map and or table that summarizes all environmental objectives by reach and time of year.

Brief text describing key features and things to note about the visualization

8 MONITORING AND EVALUATION

A monitoring and evaluation (M&E) plan will need to be designed to track the implementation, compliance, and effectiveness of conservation measures developed to meet the environmental objectives for the Stanislaus River. The M&E plan will have to match the biological objectives in its structure, because the objectives are what the conservation measures and environmental objectives are attempting to achieve. For example, the productivity objectives specify percent survival to several locations in the Stanislaus River, lower San Joaquin River, and Delta. Therefore, survival and trends in survival at each of these locations will need to be monitored and evaluated.

The SEP group considered the measurability of the biological and environmental objectives when crafting the objectives. Even if monitoring currently being conducted in the San Joaquin River basin does not directly address the specific biological objectives, the SEP group believes it is possible to design and implement an M&E plan with current technologies that will addresses the objectives.

The SEP group recognizes the need for developing an M&E plan in such a manner that the effort allocated between monitoring effectiveness and project implementation is balanced. While the primary emphasis should be on implementation, a well-designed M&E plan is a critical element of implementation because the SEP group's vision for future conditions on the Stanislaus and lower San Joaquin rivers (biological and environmental objectives) are outcome-based. To the extent possible, the M&E plan should include real-time monitoring; timely development of information will allow greater management flexibility and responsiveness to environmental conditions. The design of the M&E plan should also consider the need for evaluating previously collected data or fish tissue samples such as otoliths or fin clips. For example, studies based on information previously collected from returning adults may be used generate a post hoc distribution of juvenile life-history strategies.

There are several aspects of M&E that will need to be considered when developing the M&E plan. The studies should inform the progress made toward achieving the biological objectives. If progress is insufficient the conservation measures designed to achieve the environmental objectives will have to be modified. If monitoring cannot inform progress toward a biological objective, the M&E plan will have to be modified.

The M&E plan should also consider how it can fill key data gaps and reduce scientific uncertainty associated with key parameters and metrics. The M&E plan may also serve as a source of key data for use in parameterizing life cycle models, if such models are used to evaluate progress toward achieving the biological objectives. Development of an M&E plan should also identify the timeframe needed to replicate studies to address inter-annual environmental variability, and sampling uncertainty and error. To facilitate adaptive management, consideration should also be given to developing reporting protocols and timetables, and use of a centralized web-based database that allows all interested parties access to the data collected during monitoring.

The SEP group has not attempted to develop a M&E plan. This will occur after conservation measures designed to achieve the environmental objectives have been developed and incorporated into a formal restoration agreement or regulatory plan.. The SEP group envisions assisting with the development of such an M&E plan. As mentioned, the M&E plan will have to match the biological objectives in its structure. For example, the M&E plan will need to address the following objectives:

1. Timing of migration
2. Size at migration
3. Population growth rates that:
   - Double production in three generations
   - Ensure the population is resilient to low escapement
   - Produce egg-to-smolt survival rates of 10%
4. Holding and reproductive success of spring run Chinook salmon
5. Segregation among fall-run and spring-run Chinook salmon and among hatchery and wild spawned fish

9 ADAPTIVE MANAGEMENT

The concept of adaptive management as a means to achieve more effective decision-making and enhanced benefits to an outcome is introduced in Section 2.3.4. Adaptive management is a systematic approach for improving resource management by learning and adapting from management outcomes through partnerships of managers, scientists, and other stakeholders who learn together how to create and maintain sustainable resource systems (Sexton et al. 1999). Three elements are necessary for a program to follow the USDOI adaptive management protocol (Williams et al. 2009). First, decisions must be recurrent to allow opportunities for learning to influence future decision-making. Second, decisions must be based on predictions that incorporate structural uncertainty. Often this will be represented by two or more alternative models or hypotheses about system functionality. Third, there must be an objective-driven monitoring program. Programs that do not contain these essential elements are not, and properly should not be called, "adaptive management."

The ultimate goal of the strategies detailed in this report is to protect and further expand biological resources within the San Joaquin River basin. The biological objectives for the Stanislaus River are designed to meet this goal by establishing the ecological conditions that support the fullest expression of Chinook salmon and steelhead life-history diversity, and increase population stability, resilience, and productivity (survival) to levels that characterize viable populations. From the SEP group's perspective, the purpose of adaptive management is to enhance the likelihood of achieving the ultimate goal. From the perspective of the water districts and users, the purpose is likely to ensure that resources dedicated to achieving the goal are both effective and used efficiently.

Incorporating adaptive management into a program to achieve the Stanislaus River biological objectives serves multiple purposes. It can enhance how resources required to achieve the objectives are used, and the biological response to the resources used.

The process outlined by the SEP group for achieving the biological objectives identified in this report envisions that all three elements for adaptive management identified by Williams et al. (2009) are either described or are implicit in the approach identified. For example, while specific biological objectives have been identified, the need for monitoring has been identified (Figure 4) to measure and document compliance and effectiveness. The information developed through monitoring can then be used in a decision framework to adjust conservation measures in the future if needed, or develop new measures.

How to address uncertainty associated with Stanislaus River biological objectives will have to be discussed, and the SEP group is willing to participate in those discussions. One method for addressing uncertainty would be to establish outcomes ahead of implementation, and agree upon ways to adjust conservation measures a pirori for the various outcomes. Another would be to review an accounting of results of compliance monitoring an annual basis, and conduct formal negotiations on a predetermined schedule to make any adjusts to conservation measures if needed.

A more quantitative approach would be to utilize Adaptive Resource Management (ARM), which involves the use of quantitative models to help decision-making where outcomes following decisions are uncertain (Williams et al. 2009). In ARM, uncertainty is incorporated through the use of alternative models representing hypotheses of physical and population dynamics and statistical distributions representing error in model parameters and environmental uncertainty. Each model (hypothesis) is assigned a level of plausibility defined as a model weight, which can be assigned to each model empirically using Akaike weights, Bayesian posterior model probabilities or similar methods, or based on expert judgment of a consensus of stakeholders. The optimal decision is selected based on the current system state (e.g., spawning habitat availability) and a prediction of the expected future state following a management decision, taking into account various sources of uncertainty. After monitoring data are collected, model structure, parameter values, and model weights are updated by comparing model predictions with observed conditions and the adjusted model is used to predict future conditions and choose the optimal decision. This adaptive feedback provides for learning through time and, ideally, the resolution of competing hypotheses with monitoring data. Because of its great potential for integrating monitoring programs into decision-making, ARM has now been formally adopted by the USDOI for managing federal resources (Williams et al. 2009).

The main point is that some form of adaptive management needs to be incorporated into the implementation of conservation measures designed to meet the biological objectives described in this report. As part of the agreed upon adaptive management process, if specific targets are not being met, there should be a process established for revisiting the logic chain and the data used and assumptions made in developing the biological objectives and conservations measures. The process would allow for conservation measures to be adjusted if needed.

Adaptive management approaches are often recommended, but unfortunately, successful implementation is rare. In part, this reflects the tension between short-term preferences of stakeholders for low-cost approaches and medium- and long-term requirements for reducing uncertainty and increasing ecological certainty (Gregory et al. 2006). Thus, how an adaptive management framework is developed for the Stanislaus River needs to be thoughtfully considered.

10 DISCUSSION

The discussion section and topics will be developed in future versions of the report.

11 SUMMARY

The summary section and topics will be developed in future versions of the report.

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APPENDIX A
ENVIRONMENTAL OBJECTIVES FOR ACHIEVING THE STANISLAUS RIVER BIOLOGICAL OBJECTIVES

These matrices have been created to assist the SEP group in evaluating conservation measures within a comprehensive framework documenting habitat needs (and stressors) of three runs of anadromous salmonids in the Stanislaus River.

APPENDIX B
ENVIRONMENTAL OBJECTIVES THAT APPLY ACROSS ALL SPECIES AND LIFE STAGES

APPENDIX C
ESHE MODEL DESCRIPTION